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# DIRECTOR NOTES

I write these notes just as the program committee has completed deliberations for the 49th Shock and Vibration Symposium. Once again, I think we have a well-rounded and useful program. You may judge for yourself when you read it in the next issue of the DIGEST.

There were some problems in the paper selection process, stemming from the fact that some authors do not include proper or complete information in the summaries of their proposed papers. The program committee has a sincere desire to program all papers which offer information that advances our technology or which, in some way, offer even partial solutions to difficult problems. Since they have no way of knowing the background of the work involved, the summaries of the papers offered must contain sufficient information for them to make a proper judgement.

The ideal length of a summary is about two pages. It should be a mini-version of the paper defining the program to which it is related, the specific technological area that is involved, and the potential for application of the results. The latter is particularly important, for if one offers an obscure advancement in an analytical method with no indication as to where the advantages lie, the worth can be considered questionable. A list of references to related work is always helpful, since this assures the program committee that the authors are aware of all related work. Above all there should be a clear indication of that portion of the proposed paper that is new and different. If the value of the paper does not lie in its uniqueness, then at least clearly define what the value is.

I offer these suggestions in the interest of promoting more effective and useful symposia, and in the hope that we will not lose significant new contributions simply because a summary may have been poorly written.

H.C.P.

# EDITORS RATTLE SPACE

## THE ENERGY CRISIS -AND- THE SHOCK AND VIBRATION ENGINEER

After living with the energy crisis for several years, engineers have begun to evaluate how the crisis has affected their jobs as well as their personal lives. The shock and vibration engineer has witnessed many changes, but many of them have not involved direct energy conservation. Rather, they have to do with lightweight design to lower weights of such moving objects as automobiles. Lightweight design invariably leads to vibration problems in product design and development.

Although lightweight design has been practiced for years in the aircraft industry, it has been only recently forced upon engineers in other industries. Lightweight design requires more calculations and measurements than other design procedures to produce an adequate product. The newly developed finite element analyses have been the tools by which more accurate local stress and motion calculations can be made. These techniques are practical only when implemented on the digital computer and thus have added to the job market. Experimentalists are taking advantage of new measurement and analysis techniques for modal analysis of structures and machines. Overall, the customer is receiving a better engineered and tested product.

In some areas direct energy conservation has influenced engineering design -- for instance, the use of tilting pad bearings in turbomachinery. Conservation has also influenced the type of power generating equipment.

In the future, energy conservation will influence both the power generation industry and the power transmission industry. Windage and other damping losses will have to be assessed more accurately -- especially as equipment speeds increase. All in all the energy crisis has produced an array of new challenges and opportunities for the engineering community.

R.L.E.

# DAMPING OVERHEAD TRANSMISSION LINE VIBRATION

C.F. Beards*

***Abstract** - Aeolian vibration of overhead transmission lines can cause line failure through fatigue of the conductor, clamps, or supports. Controlling the vibration to keep dynamic stresses at acceptable levels is essential. The cause of aeolian vibration is reviewed, and several methods for controlling it are presented.*

The mechanism of vibration excitation of transmission lines caused by cross winds is well known. If the wind velocity is low, the air stream is laminar. Increasing the wind velocity -- that is, the component of the wind velocity perpendicular to the conductor and in a horizontal plane -- can cause the stream to become turbulent. Particles of air slowed on the surface of the conductor move away from the conductor and form a layer that becomes a vortex. As the wind velocity increases, separate air vortices form at regular intervals off the leeside of the conductors of the transmission line, alternately from top and bottom. This is the Karman vortex theory. Each time a vortex comes off, an instantaneous vertical force acts on the conductor, thereby exposing the conductor to an alternating force that acts vertically.

The frequency $f_s$(Hz) of this force for a cylinder of diameter D(m) in a fluid stream with velocity u (m/s) has been found empirically by Strouhal [1]

$$f_s = S(\frac{u}{D}).$$

S is the dimensionless Strouhal number. For $400 < Re < 40,000$, $S \triangleq 0.2$. This relationship has been verified for a fixed cylinder [1, 2]. The Relf-Ower relationship [3] is

$$f_{RO} = 0.185 \left(\frac{u}{D}\right)$$

If the Strouhal frequency approaches the self-oscillating frequency or a harmonic of the conductor hung between two towers, the conductor starts to vibrate in a vertical or near vertical plane, and standing waves develop on it [4, 5]. The length of the standing waves vary from two to ten meters. The nodes are not stationary, and the vibrations of the conductors increase with time.

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The smaller the cross section of the conductor, the higher the vibration frequency. The frequencies most likely to cause failure -- i.e., those creating the largest bending amplitudes for the greatest number of hours -- vary from about 6 to 80 Hz. Except on very small conductors, high frequencies are generally not dangerous, either because the damping effect of the conductor itself makes amplitudes small or they do not occur often enough. The amplitude of vibration is rarely greater than the conductor diameter.

## FACTORS AFFECTING VIBRATION AMPLITUDE AND FREQUENCY

### Initial Tension

A high initial tension of the wire decreases the magnitude of the alternating dynamic stress permissible for safety. For approximate design, the breaking stress, the yield stress, and the fatigue limit of the alternating stress with no pre-tension should be determined.

Steel-cored aluminum cable is free from internal thermal expansion forces only at the manufacturing temperature. If the working temperature is below the manufacturing temperature, there is an additional static tensile stress on the aluminium strands. During the winter months the total tensile stress of the aluminium strands increases by this static tensile strength, which is unfavorable from the point of view of vibrations.

### Wind

Wind is most dangerous at a velocity from 3 to 25 km/h. Winds of these velocities are usually rather steady and are most prevalent at sunrise and sunset [6].

### Landscape

Terrain is a very important factor in the vibration of

transmission lines. The tendency for vibration in flat open terrain is far greater than that in a forest. Vibration problems are likely to arise when the terrain guides the air stream perpendicular to the transmission line; for example, at river or valley crossings or particularly at fjord or water crossings.

The establishment of a series of terrain factors $F_T$ has been suggested [1].

$$F_T = \frac{\eta_{Prob}}{\eta_{Poss}}$$

$\eta_{Prob}$ = maximum probable vibration level as can be measured during a sufficiently long period of time.

$\eta_{Poss}$ = maximum possible vibration level as can be calculated from the energy balance of the system.

Example terrain factors have been given and their future use in transmission engineering suggested [1].

**Conductor Diameter**

Frequencies of vibration can be high with conductors of small diameter; damping becomes more difficult [3]. However, it has been stated [1] that the effect of external damping is greater for smaller conductor diameters and lower vibration frequencies. It has also been implied that a higher vibration frequency is less easily damped than a lower one, but there is disagreement on the effect of conductor diameter [1, 3].

**Separation of Conductor Supports**

Long spans are generally a disadvantage in considerations of conductor life. However, the complexity of the problem is shown by the contradiction that, with long spans, several vibration frequencies are present that reduce the vibration effect, and reduce the amplitude of vibration of each other [3].

**Conductor Material**

A decrease in the mass per unit length of the conductor increases the resonant frequencies and decreases the effectiveness of the damping [1, 3].

The cost of a self-damping conductor should not exceed that of a normal conductor by more than four to five percent to be competitive with dampers on normal transmission lines. If cost is not the ruling criterion, a self-damping conductor has several advantages over dampers.

- use of dampers creates inspection and maintenance problems. Loosening bolts in the damper clamps can cause wear of the conductor.
- with dampers, energy dissipation is concentrated at a limited number of points or to a part of the span; fatigue failure can occur in the dampers themselves.
- a self-dampinn conductor could lead to the practice of using higher conductor tensions when this is economically profitable.

For necessarily long span lengths, a self-damping conductor might be an excellent solution because damping energy is proportional to span length.

**Multiple Conductor Lines**

Although only single conductors are considered herein, it is worth noting that the vibration of multiple conductor lines is much less than that of single conductors. The vibration of multiconductor lines without spaces is approximately 33 percent of that of a similar single conductor [3]. With spacers attached, the vibration is only 20 percent of the single conductor amplitude.

## CONDUCTOR STRESSES

Wherever a conductor is restrained, vibration causes stress on the conductor strands, and damage can occur because several other stresses are inflicted on the conductor at the strands.

The main stresses acting on the conductor are static and dynamic.

- static stresses
  - tensile stress due to tensioning.
  - bending stress at the suspension clamp.
  - compressive stresses at the suspension clamp.
- dynamic stresses
  - alternating bending stress during vibration.
  - tensile stress due to variation in length of the conductor.

- additional deformation stresses due to the possible collision of the suspension clamp with the wire.

Dynamic stresses caused by vibration are superimposed on the static stresses. The number of oscillations in a day can be as high as several hundred thousand; thus, individual conductor strands can break without warning if the fatigue limit is exceeded. Evidence has shown that the strands most likely to break are near the suspension clamps [4].

In much of the literature [1, 2, 6], the term Every Day Stress (E.D.S.) has been used because these stresses are difficult to calculate. The E.D.S. is the mean tensile stress in the wire at the average yearly temperature.

Dynamic stresses can increase the total stress as much as 50 to 60 percent of the breaking stress in a conductor with 20 percent line tension [3]; sources recommending a line tension of only 15 percent are mentioned. Reducing the static tension tends to decrease the tendency to vibrate; this decreases the frequency of vibration, thus increasing damping effectiveness.

## METHODS FOR CONTROLLING CONDUCTOR VIBRATION

The most well known methods for controlling conductor vibration include

- using a steel-cored aluminium twin cable that provides two mechanical structures independent of each other.
- strengthening the conductor at the suspension clamp by attaching a piece of cable.
- strengthening the conductor by elastic spirals of plastic.
- strengthening the conductor by armor rods of various types.
- fixing vibration damping cables.
- reducing static tension in the conductor.
- properly constructing suspension fittings.
- using vibration dampers with tilting rods that produce disturbing vibrations by collision.
- using a Stockbridge vibration damper.
- using a torsional damper.
- using vibration dampers with piston or spring loads.
- using a self-damping cable.

**Armor Rods and Armor Grip Suspension Units**
Three types of armor rod [1] are used. In one, the conductor is covered by two layers of wires having a flat, rectangular cross section in a direction opposite the conductor. In another type, the conductor is covered by another layer of wires at the suspension point for a short distance on both sides. Cylindrical aluminium armor rods are used to protect wires with diameters up to ten mm. The third type is for wires of larger diameters; 10 to 12 conical aluminium armor rods are used with fastening rings on both ends.

Whatever armor rod is used reduces the stress acting on the conductor at the suspension points by covering the conductor so as to increase the cross section, thus strengthening the conductor. The rods protect the conductor from mechanical damage caused by flashovers and reduce attrition.

Rather than reduce vibration the armor rods limit the damaging effects of vibration on the conductor. The rods reduce the dynamic stress of the conductor at the suspension points by approximately 30 to 50 percent and the amplitude of vibration by perhaps 10 percent.

The use of dampers and armor rods to reduce dynamic stress has been discussed [7], but the article is concerned more with the use of Armor Grip Suspension units (A.G.S.). The results of laboratory tests have shown that the A.G.S. unit reduced the static bending by approximately 70 percent, the damping stress by approximately 80 percent, and the dynamic stress by approximately 45 percent. The successful use of this type of support in several cases is described; the support recommended is the wraplock tie, which cannot work loose and for which abrasion is nonexistent. Because both the tie and the conductor are cushioned in Neoprene, clamping stresses are negligible.

Armor rods have also been used with conductors embedded in Neoprene [3]. The stress at the conductor support clamp is about 35 percent of that for a conductor without armor rods and 60 percent of that for a conductor with armor rods.

### Single-Degree-of-Freedom Damper

A single-degree-of-freedom damper containing a filler material that confines the conductor over an appreciable length has beeen described [8]. The damper consists of a rigid outer casing in the form of a two-piece cylinder. The inside diameter of the casing is about three times the conductor diameter. The space between the casing and the conductor is filled with a spongy material. The resonant frequency of the single-degree-of-freedom mechanical system is determined by the stiffness of the filler material and the weight of the casing. The filler stiffness and casing weight are selected so that the damper resonance frequency is below the excitation frequencies produced by prevailing winds. Under these circumstances the casing remains relatively motionless in space. A wind that tends to produce standing wave motion in the conductor causes compression of the spongy filler. The filler provides a resistance against any motion, and kinetic energy is absorbed by the damping of the filler.

The significant characteristic of this damper is that its dynamic stiffness remains almost constant (200 kN/m) at all frequencies above resonance. The damper thus provides resistance to and damping of vibrations at frequencies throughout the range of prevailing winds. Extensive laboratory and field tests of this damper have demonstrated its effectiveness [9].

### Spiral Vibration Damper

Spiral vibration dampers consist of an elastic spiral of plastic material wound around the conductor. Initial experience with this damper has been favorable [3].

### Vibration Damping Wire

The vibration damping wire is hung on the conductor and connected to it at several points. This method can be used quickly and requires no special fittings. It can also be used to take some of the load off aluminium strands that are broken.

### The Stockbridge Vibration Damper

The Stockbridge damper consists of two masses resiliently suspended from the conductor. The masses are rigidly attached to the ends of a horizontal steel cable, which in turn is attached at its midpoint to the conductor.

The purpose of the damper is to absorb wind energy and so prevent the development of vibration. Because of the high weight of the masses, the steel supporting cable is not stiff enough to force the masses to follow accurately the motion of the cable clamp. The result is flexure of the supporting steel cable; the flexure is particularly large when the damper responds at one of its own natural frequencies (damper resonances). The flexure causes slippage between strands; the result is dissipation of energy by interstrand friction.

The damper -- if properly installed -- reduces the dynamic forces by approximately 90 percent within the usual frequency range. It also prevents the transmission of vibrations to insulators and poles. The response characteristics of the Stockbridge damper have been analyzed [9, 10]. Expressions have been derived that consider the damper as a two-degree-of-freedom system. Dynamic stresses have also been calculated and compared with experimental results [9, 10].

### Single Mass Absorbers

Single mass absorbers include those consisting of an arm carrying a conductor clamp and attached to a single absorber mass with the center of gravity offset from the effective center of suspension by a spring. The absorber mass has at least two coupled modes of vibration at distinct frequencies.

The degree of mode coupling is determined by the inertia and spring stiffness values of the system. Thus, proper selection of these values will result in a vibration absorber with up to six resonant frequencies spread over the desired frequency range. Damping can be introduced by a rubber spring. This system is the basis of a patent published in 1970 [11, 12]. Disadvantages of this type of vibration damper include difficulty of production and expense.

### Dual Dynamic Absorbers

Either a three-element absorber or dual dynamic absorbers can be much more effective in reducing vibration than the conventional absorber [13]. The dual dynamic absorber is applicable to transmission line vibration, and it can be inferred that two dampers placed close to each other on a transmission line would be much more effective than the single damper. Further work related specifically to transmission line vibration would be necessary to assess relative

advantages.

**Conductor Self-Damping**

Energy can be dissipated in a vibrating conductor in various ways.

- material damping; i.e., the energy dissipated in solid matter inside the individual conductor strands.

- interface slippage damping which originates at the points of contact of individual strands and is associated with coulomb friction.

- air resistance (very small).

Other factors can influence the self-damping of a conductor after it has been erected. Creep should improve the damping due to the reduction in tension of the outer wires; however, it is generally found that old conductors have less self-damping capacity than new ones, perhaps because of the higher degree of compactness after creep and possible modification of the friction coefficient on the interface. The addition of grease does not always improve damping.

On normal stranded cables self-damping is definitely associated with coulomb friction. Although all conductors are self-damping to some extent, special self-damping cables have been designed. With such cables it is of prime importance to assure that the individual strands are not locked together too tight when tension is increased.

Details of the designs of some self-damping conductors have been published.

- use a hollow conductor with a core that is free to move and erected such that the hollow part and the core have different resonant frequencies. Soft metal between the layers increases self-damping [14].

- a 1968 U.S. patent describes a conductor that avoids forceful radial contact between layers in the conductor [15].

- a Norwegian patent describes another method for introducing very high coulomb friction [16].

Heavy wear in the conductor is avoided because of the low vibration and the fact that the self-damping takes place across the entire span. Laboratory testing techniques on self-damping conductors have been described [17].

## CONCLUSION

Increased conductor static stress levels are allowable if a damping device is installed to control dynamic stress levels; e.g., addition of dampers allows greater spans between towers, making operation economically feasible. A range of damping devices can be attached to a conductor; the most widely used is probably the Stockbridge damper. Self-damping conductors provide good vibration attenuation but at greater cost.

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# LITERATURE REVIEW

**survey and analysis of the Shock and Vibration literature**

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains the final article of the series on seismic waves by S. De. Part IV on seismic waves is devoted to mathematical methods.

Professor Filho of the Federal University of Rio de Janeiro has written an article on the finite element analysis of structures under moving loads. This review deals with utilization of the finite element method to obtain stiffness properties and the properties of mass of the structural system and the mass of loading due to a moving vehicle.

# ON SEISMIC WAVES
# PART IV: MATHEMATICAL METHODS (2)

**S. De***

***Abstract** - This second article on mathematical methods includes a brief discussion about earthquake prediction. Suggestions for future research are given in this final section.*

## OTHER PROBLEMS

The reflection and transmission of Rayleigh waves in a wedge has been considered [1] **. The reflection of a Rayleigh wave traveling on one face of an elastic wedge when a rigid obstacle is in shearless contact with the other face has also been calculated. The results are valid for wedge angles less than 90°. The reflection and transmission of Rayleigh waves in a wedge for incidence from infinity and for the more general case of incidence from infinity and for the more general case of incidence at a finite distance from the corner have been studied [2]. The effect of the critical regions of Rayleigh waves in Lamb's half-space when the regions interact with the wedge faces were considered.

Green's function was used to represent an SH-line source in a wedge-shaped nonhomogeneous medium [3, 4]. For certain distributions of density and rigidity all rays approached the vertex of the wedge after they had been reflected from the plane boundaries.

The diffraction of elastic waves by a half-plane has been described by parabolic coordinates [5, 6]. The defraction of compressional waves by a rigid barrier in a liquid layer or half-space has also been considered [7], as has diffraction of SH waves from a point source by a rigid or fluid spherical core [8]. The integral for a field created by a line source of harmonic SH waves embedded in a semi-infinite medium whose density and rigidity vary exponentially with depth has been derived [9].

The use of a circular source to generate and propagate SH disturbances in an elastic half-space has been described [10]. The source was a time-dependent discontinuity in the shear stress. The scattering of polarized harmonic shear waves by a sharp crack of finite length under antiplane strain has been considered using integral transforms [11]. Tsepelev [12] investigated a shadow zone at the boundary of a nonhomogeneous half-space.

Photoelastic techniques have been used to study the incident, reflected, and refracted waves in a layered model [13]. Diffraction and reflection of compressional waves incident on a rigid quarter-space in shearless contact with a homogeneous isotropic elastic half-space have also been examined theoretically [14]. Wiener-Hopf techniques were used to separate the diffracted and reflected waves at any point in the medium.

Plane P and SV waves incident at the base of a dipping layer and perpendicular to the strike have been investigated with a technique that expresses reflection and refraction coefficients in terms of the direction of propagation of the incident wave in a cylindrical coordinate system [15]. The method of Miles has been used to obtain a homogeneous solution for the diffraction of a plane pulse due to a plane smooth rigid barrier at the surface of separation of a semi-infinite elastic solid and a semi-infinite liquid medium [16]. Complex variables and characteristic theory were used. Displacement components at the wave fronts and in the simple wave zones were derived in a closed form.

The reflection and diffraction of Love waves due to a vertical crack in an infinite elastic layer of finite thickness attached to a rigid half-space have been studied [17]. Approximate values for displacement due to reflected and transmitted waves were derived by assuming that the width of the crack was much less than the thickness of the slab [18]. The correct formula for the scattering cross section in the Rayleigh limit was sought for a plane harmonic wave scattered by an elastic sphere. The interaction of a half-space, several infinite coaxial cylindrical layers, an an inclusion during excitation of a plane harmonic

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**See the April, 1978, DIGEST for the complete list of references

SH wave has been solved by the method of wave function expansion [19]. Displacement as a function of space and time was derived for one layer and an inclusion. Three cases of elastic inclusion were considered: half-space, elastic layer, and rigid layer.

The transient scattering of waves by an island surrounded by water depth of variable depth has been studied by using a finite difference integration in the nonhomogeneous region that ends at an outer boundary [20]. An exact relationship between wave heights and velocities -- a Kirchoff-time-retarded integral equation -- was used at the boundary. The two-dimensional interaction of step-function compressional wave and a circular cavity in an infinite elastic medium has been described [21].

The generalized ray theory has been used to investigate primary- to shear-mode conversion at the ocean bottom [22]. The author concluded that this analysis adequately determined crystal elastic parameters.

The effect of stratification of an overlying rock mass on the amplitudes of reflected and head waves has been studied theoretically [23]. A ray-approximation for ideally elastic, homogeneously stratified media with horizontal boundaries was used. The reflection and transmission of plane SH waves has been presented for two half-spaces [24]. The upper half-space was an elastic medium and the lower one was a form of viscous medium. Numerical evaluations of reflection and transmission coefficients and their phase changes were given for various viscosity models.

It has been shown that a Rayleigh wave occurs as a result of the constructive interference of a nonhomogeneous P wave with a nonhomogeneous SV wave [25]. The nonhomogeneous waves have prograde elliptical particle motions, but their combination produces retrograde motion near the surface. The two nonhomogeneous waves were the only nonhomogeneous waves allowed in a homogeneous elastic half-space. However, non-allowed nonhomogeneous waves often adequately represent wave motion over a restricted area -- a fact that can be demonstrated for leaky modes and propagation of a Rayleigh wave on a three-quarter space.

Kennett [26] related conventional matrix methods for layered media to the reflection and transmission properties of a single layer. He used the relationship to set up an iterative approach for calculating reflection and transmission coefficients in multilayered media.

The reflectivity of nonhomogeneous media and arbitrary depth-dependence of the elastic moduli and density have been studied [27]. An integral of the wave equation was derived and a numerical solution presented. This formulation allowed separate determination of the influence of density, compressibility, and frequency on the reflection of plane waves. The method was applied to laminated nonhomogeneities and to gradient zones. In order to obtain rays the Rayleigh matrix -- not the Rayleigh determinant -- should be used to expand the solution into a power series of modified reflection and transmission coefficients [28].

An exact solution has been obtained for the reflection of a plane shear wave at a regular stratified half-space [29]. The finite difference iterative method [30] yielded full wave solutions for problems without exact solutions that involved scattering of the elastic surface at vertical discontinuities in homogeneous media. Coda waves from small local earthquakes have been interpreted as backscattering waves from numerous heterogeneities distributed uniformly in the earth's crust [31].

Wave propagation in an infinite micropolar elastic half-space and the reflection of plane longitudinal displacement waves from a fixed flat surface of a micropolar elastic half-space have been investigated [32]. Reflection laws and amplitude ratios were presented. Reflection and transmission of a propagating stress discontinuity incident at a smooth interface between two homogeneous isotropic linear elastic materials having different material parameters was studied using the ray theory [33].

The refraction of a seismic wave when it arrives at the surface of the earth has been studied [34]. Coulomb dry-friction boundary conditions were used to examine the refraction of a plane elastic wave at the surface of an elastoplastic medium. Other problems of interest regarding reflection and diffraction of seismic waves have been published [1, 35-54].

This disturbance created by transient torsional forces in a non-isotropic layer of finite thickness

standing on a semi-infinite non-isotropic homogeneous elastic medium has been discussed [55]. An exact expression for the disturbance due to a point SH source in a medium consisting of many heterogeneous spherical shells and second order discontinuities has been obtained [56]. Long [57] reviewed the theory of body and surface waves relative to the core, mantle, and crust. It has been reported [58] that travel times of body waves and dispersion of surface waves indicate that low velocity layers are relatively thin zones containing regions in which high velocities can occur.

Travel times of S and SKS for arc distances ranging from 30° to 126° have been reported [59]. The times for S did not differ significantly from the Jeffreys-Bullen tables up to 80° and were up to 4 sec later between 80° and 100°.

Expressions have been obtained for ray-theoretical spectral amplitudes of body waves induced by a shear dislocation of arbitrary orientation and depth situated in a radially heterogeneous model of the earth [60, 61]. Body-wave magnitudes $m_b$ and surface-wave magnitudes $M_s$ have been determined for 100 events in Eurasia that occurred from August, 1971, through December of that year [62]. Some interesting problems regarding body waves have been reported [63-67].

## ANALYSIS OF EXPLOSIONS

The propagation of an impulsive disturbance has been studied with a Fourier integral usually used to represent an initial disturbance as the summation of a complete spectrum of simple harmonic waves with proper initial phases and amplitudes. If the phase velocity is a function of period as is true of Love waves, the initial pulse is distorted because the component waves travel outward with different velocities. At some distant point the initial pulse is transformed into a train of sinusoidal waves in which period and amplitude vary gradually along the train [68]. The generalization of plane, steady-state surface waves as an impulsive source of limited extent has been discussed [69, 70].

The disturbance generated in a semi-infinite medium by a suddenly applied vertical force was studied by Pekeris [70]. He obtained closed form expressions for the displacements in the radial and vertical direction on the surface $z = 0$ and found three distinct wave fronts that travel with the following velocities

$$c_1 = [(\lambda + 2\mu)/\rho]^{1/2},\ c_2 = (\mu/\rho)^{1/2},\ \text{and}\ c_R = c_2/\gamma.$$

The arrival of Rayleigh waves was marked by an infinite discontinuity in both $u_r$ and $u_z$. An analogous solution in a viscoelastic medium has been given by Miklowitz [71], who used double integral transforms. He studied pulse scattering by a circular cylindrical cavity in an infinite solid, a problem of interest in protective construction [71]. The Rayleigh waves produced by pressure on the surface of a semi-infinite elastic medium have been studied [72]. The expression for displacements at a large distance and numerical calculations for a particular form of the applied pressure were considered.

Cagniard's method and integral transforms have been used extensively to calculate the time response of a half-space. For example, SH disturbances due to a discontinuity in shear stress across a circular region have been considered [10], as has the displacement field due to a torsional disturbance produced by an expanding source [73]. The disturbance produced in a homogeneous anisotropic half-space when a normal force is suddenly applied at the surface has also been studied [74]. Surface displacements have been obtained for a finite SH line source in a layer lying over a semi-infinite medium [75].

The propagation of radial and rotational waves when a blast pulse is produced inside the surface of a spherical cavity of radius a in an infinite nonhomogeneous elastic solid consisting of spherically-aeolotropic material has been considered [76]. When the material is the mineral barium sulfate (barite), the displacement of radial waves is given by

$$u_r = \frac{2P_0 a^2}{T} \quad (a/r)^{3/2} \frac{A}{B}$$

where

$$A = [2e^{-\tau^1}\alpha_1 \left(ae^{\frac{-\alpha_1 T_1}{a}} \cos\frac{\alpha_2 T_1}{a} - a - \alpha_1 T_1\right)$$

$$\left\{(a - \alpha_1 r)\cos\alpha_2\tau^1 - \alpha_2 r \sin\alpha_2\tau^1\right\} - (\alpha_2 T_1$$

$$- ae\frac{\alpha_1 T_1}{a} \sin\frac{\alpha_2 T_1}{a})$$

$$\left\{\alpha_2 r \cos\alpha_2 \tau^1 + (a - \alpha_1 r)\sin\alpha_2 \tau^1\right\}]$$

$$B = [(\alpha_1^2 - \alpha_2^2)\left\{4a_{11}\, a\alpha_1 - a(4a_{12} - 3a_{11})\right\}$$

$$+ 8\,\alpha_1\alpha_2^2 a]$$

with

$$c_{ij} = a_{ij}/r,\ \tau = \sqrt{c_{11}/\rho_0}\ t,\ \rho = \rho_0/r$$

The boundary condition satisfied by the radial blast pulse on the surface of the spherical cavity of radius a is

$$(\tau_{rr})_{r=a} = \begin{cases} -P_0\,(1 - t/T) & 0 < t \leqslant T \\ 0 & t > T \end{cases}$$

$$T_1 = \sqrt{c_{11}/\rho_0}\ T,\ \alpha_1 = \frac{3a_{11} - 4a_{12}}{4a_{11}}$$

$$\alpha_2 = \sqrt{(4a_{12} + 5a_{11})(3a_{11} - 4a_{12})}\ /4a_{11}$$

$c_{ij}$ are the elastic constants, $\rho$ is the density, and $\rho_0$ is a constant.

The displacement of rotational waves is given by

$$u_\phi = \frac{-P_0 a^3}{a_{55} T_1}\,(a + T_1 - a\,e^{T_1/a})\,e^{(1/a)(r-\tau_1)^{-1}}\sin\theta,$$

$$c_{ij} = a_{ij}/r^2\,, \qquad \tau_1 = \sqrt{a_{55}/\rho_0}\quad t\,,$$

$$[\tau_{\phi r}]_{r=a} = \begin{cases} -P_0(1 - t/T)\sin\theta & 0 < t \leqslant T \\ 0 & t > T \end{cases}$$

The same problem in the case of a cylinder and an aeolotropic medium has been studied with Laplace transforms [77]. The application of a uniform time-dependent pressure $\phi(t)$ -- such as that produced by an explosion -- on the surface of a spherical cavity propagates spherically symmetric elastic and plastic stress waves into the solid media. The theory of elastic-plastic waves has been applied [78].

The propagation of time harmonic waves in an isotropic elastic half-space containing a submerged cylindrical cavity has been solved analytically [79]. Linear plane strain conditions were assumed. The elastic potentials were expanded in a series that automatically satisfies the following: the governing equations, the conditions for zero stress on the flat surface, and the radiation conditions at infinity. The production, amplification, and reflection of Rayleigh waves were dealt with.

A finite line source in an infinite elastic medium was reconsidered by Viswanathan [80]. He simplified the method by treating the line source as equivalent to an appropriate distribution of point sources over the surface of a prolate spheroid that degenerates into the line source in the limit when its minor axis tends to zero. Green's functions were used.

Shock wave propagation in a solid with variable internal properties has been investigated [81]. Exact solutions were obtained for the amplitude of compressive and expansive viscoplastic waves. Equations for elastic-wave propagation caused by an explosive point source were solved by a finite difference scheme [82]. An elastic wedge having free boundaries that form an angle $0° < \theta < 180°$ was used.

The disturbance due to a line source buried in a homogeneous elastic half-space with hexagonal elastic symmetry has been investigated with a combination of Fourier and Laplace transforms [83]. Cagniard's method was used to obtain exact closed algebraic expressions for the surface displacements as functions of time and horizontal distance valid for all epicentral distances. The complete motions of an elastic quarter plane and of a three-quarter plane with free boundaries caused by an explosive point source were obtained with finite difference methods [84]. Cagniard's method also applies to a model of a point source of torque in a layer overlying and welded to a half-space of higher velocity. Such a model was used to approximate long-period $SH_n$ waves recorded from regional shallow earthquakes in California. The model is consistent with a crystal thickness of about 20 km in extreme west-central California. An effective source pulse of 10 sec appears reasonable for the earthquake, the magnitude range of which was 5 to 5.5 on the Richter scale.

A closed form solution has been obtained in a nonhomogeneous elastic medium for the propagation of waves resulting from a sudden impulsive radial force on the wall of a spherical cavity in the medium [85]. The expression for surface displacements due to a circular point source at a fixed depth below the

free surface of an elastic half space has been found using transform methods and Cagniard's techniques [86]. The expressions were evaluated in terms of elementary functions and elliptic integrals when the ring lies on the surface.

A unified approach for studying two-dimensional plane and axially-symmetric stress waves is given [87]. It has application to the analysis of seismic waves and to explosive formation of long tunnels. The propagation of Love waves due to a point source in a nonhomogeneous medium has been studied [88] using Green's function.

A spherical theory for perturbations of the earth's rotation by major earthquakes and explosions has been presented [89]. It has been reported [90] that the Biswas-Knopoff transformation can be used to modify programs for computing the Love-wave response to a point source in a flat structure so that the response in a sphere can be calculated. A technique has been developed that increases the utility of surface wave spectra for characterizing seismic sources [91]. Some problems of interest have been described [92-100].

Asymptotic high-frequency properties of the field resulting from a point source of SH waves in a non-uniform half-space with a waveguide near the surface have been investigated [101]. A theoretical study -- a special case of a relaxation source -- has been reported for seismic wave radiation resulting from sudden deformation of a spherical fluid region in an infinite elastic medium subjected to pre-existing shear stress [102].

Basic characteristics of seismic waves in both the near- and far-field have been clarified [103]. Exact solutions for free surface displacements generated from a shear fault with an arbitrary orientation in a semi-infinite medium were obtained using a cylindrical coordinate system. Expressions for displacements with respect to time were derived from Laplace transforms. Exact transient solutions were obtained from Cagniard's method, which gives inverse Laplace transforms in an ingeneous manner when the source time function is of the ramp type.

Multimode, Rayleigh-wave response characteristics for strike-slip sources have been summarized [104]. The sources are located at various depths within the crust of a shield structure. Displacement components were obtained for a compressional point source in a layered half-space consisting of a liquid layer of finite thickness, overlying a semi-infinite solid homogeneous medium [105]. Horizontally polarized wave motions generated at the free surface of an elastic half-space by a strike slip on a fault plane having an arbitrary dip have been analyzed [106]. Wave motions generated by slip in the vertical mode with friction on a fault plane of arbitrary dip have also been analyzed [107].

A point-source excitation of Rayleigh and Stoneley waves on the boundary of an elastic medium consisting of a liquid or gas has been solved for a short-wave approximation [12]. The limiting case, in which the elastic medium bounds a vacuum and undamped Rayleigh waves are generated, was also considered.

Elastic-wave propagation in two evenly-welded quarter spaces has been considered [108]. A compressional line source could be located at any point in either medium. A solution to the dynamic problem for a half-plane of viscoelastic material with an instantaneous point source on the boundary has been published [109]. The vertical displacements generated at the surface by a buried vertical dipole in an elastic half-space have been determined [110]. The dipole was assumed to be dependent on ramp time.

Records of microseisms produced by cyclones in the Bay of Bengal have been analyzed to precisely determine the location and size of the source [111]. It appears that the microseisms were not pure Rayleigh waves and that the Love waves contributed about 25 percent to the total disturbance.

It has been shown that Love waves can be generated even by small explosions [112]. Properties of the wave group that seems to consist of Love waves -- including direction of wave vibration, dispersion, amplitude, and spectrum -- were investigated. The energy ratio of Love waves to Rayleigh waves due to the explosive source was only a few percent. Some problems of interest regarding seismic waves created by explosions have been given [113-138].

A complex group of waves with mixed Love and Rayleigh-motion has been observed at the end of a surface-wave train recorded at stations across Canada

and United States. It might be associated with an earthquake that occurs several minutes after the explosion. It has been shown that surface-wave magnitudes computed for Love waves are smaller than magnitudes computed from maximum surface-wave amplitudes [137].

The excitation of long-period (15 to 70 sec) Rayleigh and Love waves by earthquakes, underground explosions, and presumed explosions was studied between August 1, 1969, and July 1, 1970 [126]. The duration of ground motions due to earthquakes and nuclear explosions has also been considered [139]. The generation of P and S waves by underground explosions produced in spherical cavities has been described [140] and an expression for the transfer function of the source established. Two electronic models were then designed to simulate underground explosions that generate P and S waves.

Long-range observations of explosions have been widely used to obtain detailed information about the structure of the upper mantle [113]. Amplitudes of Rayleigh waves generated by nuclear explosions and cavity collapses in southern Nevada have been analyzed [141]. Computer models have been used to estimate the Rayleigh wave-generating efficiency of various configurations of dilatational sources beneath different topographies [142]. Concentrated sources, as well as vertically- and horizontally-distributed sources beneath mountains, canyons, and plains, were considered. The horizontal dimension of the source had the greatest effect on the amplitude of the Rayleigh waves.

Theoretical evaluations of the parameters of seismic waves have been compared with published experimental values pertaining to nuclear explosions [143]. A theoretical model of sub-surface explosions included a description of rock behavior during explosions, a description of the source of motions caused by the local release of a large amount of energy, and a technique for obtaining numerical solutions to the equations [144]. Compressional and shear wave velocities have been measured in silica sand, volcanic ash, and powdered basalt subjected to hydrostatic pressures ranging from 1 atm to 2.5 kb [145]. Excitation of Love waves by large underground nuclear explosions at the Nevada test site has been reported to differ from that by small explosions at shallow depths [146]. The large explosions depend on shallow depth and their characteristics change with repeated experiments.

A technique for interpreting source mechanisms for nuclear explosions using Rayleigh and Love waves has been described [147]. Theoretical calculations of stress wave pulse shapes from an explosive source in a cavity were carried out for two- and three-dimensional geometry. The generation and development of Rayleigh waves from a point source in a half-space were studied with the Cagniard-deHoop technique.

Velocities of earth particles after sonic booms have been recorded at Edwards Air Force base, California; at the Tonto Forest Seismological Observatory near Payson, Arizona; and at the United Basin Seismological Observatory near Vernal, Utah. Analysis of the field data indicates that the lateral seismic effects of sonic booms are confined to the area of the boom pressure envelope; vertical seismic effects are confined to the upper few meters of the earth's surface [148]. An exact solution has been obtained for the displacement of the surface of a layered sphere caused by an explosive point source within the sphere [149]. The duration of the ground motions associated with earthquake and nuclear-explosion has been studied [139].

## MODELS

A technique for assessing disturbances resulting from the application of dynamic couples at a point beneath the surface of an elastic half-space has been presented [150]. The technique provides a basis for earthquake modeling because disturbances from couples simulate the elastic motion that follows a fault dislocation in the presence of an initial strain state. This study did not involve a particular model but does provide a way -- by superposition of five fundamental double force cases -- to determine the disturbances for any model.

A general procedure based on finite element analyses of actual equipment and building configurations has been developed to determine earthquake bracing loads [151]. A study of a nine-story steel frame building during the San Fernando earthquake of February 9, 1971, showed actual dynamical properties of the building during the earthquake and dem-

onstrated that, when ground motion is specified, accurate predictions of building motions during moderate earthquakes can be made from a linear viscously damped model [152]. Similar problems have been studied [153-155]. Fourier amplitude spectra have been compared with response spectra from ground motions recorded during the San Fernando earthquake at selected sites in Los Angeles [156].

The surface-wave theory required to predict ground-motion time histories has been used to study the contribution to ground motion of the arrival of multiple-mode surface waves [155]. Multiple-mode surface-wave signals were used to model ground motion at distances ranging from 50 to 500 km for an earthquake source in the interior of a continent. Motion on a thrust fault was used as the earthquake model.

***Prediction of earthquakes.*** Work has been reported concerning the prediction and minimization of earthquake intensity. Earthquakes cannot yet be predicted with complete certainty because the mechanism that produces them is not fully understood. It is believed that an earthquake is the termination of a series of events that have occurred in the earth's interior. Most predictions made by seismologists are based upon statistical data and considerations of probability theories. Berckhemer [157] suggested that the biggest current problem in seismology involves attempts to accurately predict a single earthquake. Promising results have been published [159-161].

Results of a long-term Japanese research program on earthquake prediction have been outlined [162]. A tentative strategy for predicting earthquakes is proposed, and an attempt is made to evaluate earthquake threats on the basis of probability theory. Earthquake prediction based on station residuals has also been considered [163]. Whitcomb and Garmany [164] suggested that a large change is seismic body-wave velocities occurred before an earthquake in San Fernando, California. The discovery that the change was mainly in P-wave velocity can be related to dilatancy in fluid-filled rocks. An earthquake prediction model has been proposed in which stress causes micro-dislocations that create elastic waves which are propagated from the dislocation site [165]. In the period just before an earthquake the average sizes of microfracture increase, causing not only an increase in acoustic energy but also a skewing of the power spectral density toward more dominant lower frequencies.

The tidal effect of the moon on the earth's crust in relation to earthquake prediction has been considered [166]. The likelihood of earthquakes was analyzed by combining data from space photographs, inferred structural lineaments, geological records of fault lines, and a seismic history of the area. Kisslinger [167] reviewed methods for earthquake prediction -- seismicity gaps, recurrence rates, and changes in geodetic measurements. He stressed changes that might occur in physical properties before the onset of an earthquake -- elevation of benchmarks, increased velocities of seismic waves, and changes in electrical and magnetic properties of crustal rocks.

The theory of elasticity is used to predict the effect of initial stress on the propagation velocity of elastic waves. The theory has also been used to predict the occurrence of earthquakes [168]. Variations in earth stresses should be associated with changes in the velocity of seismic waves; stress changes indicate critical changes in tectonic stresses. The mathematical foundations for studying the effects of pre-strains have been established [169].

A recent major earthquake (magnitude 7.3) near the town of Haicheng, China, was predicted with enough certainty that people were warned [170]. The prediction was the result of a synthesis of many investigations, but the methods used for long-, mid-, and short-term predictions were apparently based on studies of seismicity, deformation, and foreshocks respectively.

Whether or not an earthquake is periodic has been considered [171]. It has been reported [172] that seismic safety during underground nuclear explosions involves special problems: (i) forecasting the main parameters of seismic waves as a function of yield and depth of the explosion, distance from the point of the explosion, and the geological conditions both in the region of the explosion and along the path of the seismic waves at buildings and other structures; (ii) assessing the possible effects of waves on buildings and other structures with regard to type, design, and condition based on the predicted values of the

main parameters of seismic waves; and (iii) determining the measures required to provide seismic safety, including the maximum permissible yield of the explosion. A system for extinguishing seismic surface waves that arise during an explosion is designed in the form of a chain of holes filled with porous material [173]. Blast holes were arranged around the source of the seismic waves; the mouths of the holes were made with widened funnels.

## FUTURE RESEARCH

Insofar as future research is concerned, the study of seismic waves from small explosions should be emphasized, for such studies will provide clues to the detection of mineral beds. Waves resulting from explosions in the atmosphere should be studied to determine if coupling occurs between the atmosphere and the ground. Weak and strong shock waves during explosion at low and high altitudes should be studied. The hydrodynamic effects of blasts at relatively low altitude should be determined, as should any effects of earthquakes on the period of oscillation of the entire system.

The mathematical study of certain problems -- cavitation zone and wave profile -- associated with underwater and underground explosions should be emphasized. It has been suggested that large volumes of material deep inside the earth suddenly crystallize and produce earth vibrations. The study of waves in both crystalline and liquid media should thus be emphasized. Plastic flow should be studied because the behavior of rocks is thought to be plastic deep within the earth.

The classification of earthquakes as tectonic, volcanic, or impact should be studied. Standard earth models should be designed to predict and minimize earthquake damage. Mathematical solutions to the problem of sound radiation from waves generated by earthquakes should be better understood. Effects of earthquake generation on the oscillation of the ionosphere should be studied.

Little work has been done on the nonlinear theory of seismic waves. Mathematical techniques for solving nonlinear wave problems should be emphasized in seismology. The study of wave propagation in prestressed media and of plate tectonics should be encouraged. Finally, the influence of stress on wave propagation in stratified geological structures should be studied.

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# FINITE ELEMENT ANALYSIS OF STRUCTURES UNDER MOVING LOADS

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***Abstract** - This review is concerned with the utilization of the finite element method to obtain stiffness (or flexibility) properties and the properties of the mass of the structural system and of the mass of the loading due to a moving vehicle. A general equation is formulated and specific cases and their methods of solution are described. Significant contributions are reviewed and related whenever possible to work involving continuous or approximate approaches. Areas of further research are indicated.*

The dynamic analysis of structures under moving loads has attracted the attention of engineers since the 1800s. Early investigations were concerned with the study of railway bridges and the behavior of highway structures under moving vehicles. Dynamic effects were not great because of the relatively low speeds of the vehicles. High-speed transportation vehicles have increased the importance of dynamic analyses, however. The first dynamic analyses of structures under moving loads involved a simply supported beam in two limiting cases:

Case 1. a load with a mass traversing on a massless beam

Case 2. a massless load traversing with constant velocity on a beam with uniform mass.

Case 1 applies to railway bridges and has been analyzed [23, 34]. Stokes [23] solved the problem of a beam with a uniformly distributed mass traversed by a massless load with constant velocity. Case 2 has also been studied [13, 16, 26]. Timoshenko [26] integrated the differential equation of the forced vibrations of a simply supported beam by modal superposition. He stated that the maximum dynamic deflection is 1.5 times the static deflection when the traversing time is half the first natural period of the beam. It was later recognized [7, 32] that the situation is less conservative: the maximum deflection is 1.743 times the static deflection. This corresponds to a traversing time of 0.81 times the first natural period. This conclusion was later supported using finite element methods.

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Analytical solutions corresponding to Case 2 for other types of beams have been presented for a two-span continuous beam [1] and for cantilever beams [20]. The case of the moving sprung load has also been treated [20], as has the response of orthotropic plates traversed by a constant force [24].

Timoshenko [27] studied the case of a simply-supported beam traversed by a moving alternating force. The same problem with a two-span continuous beam was verified experimentally [2].

The first attempt to include the mass of both the beam and the moving load was in 1929 [14]. The problem was later simplified by assuming that the dynamic deflection curve at any time is proportional to the first normal mode of vibration of the beam [11, 13, 17]. More accurate analyses of this problem have been presented for simply-supported beams [21], one- and two-span beams [3], and cantilever beams [36]. Some of the work [3] is experimental but includes theoretical verifications based on results for the massless load and on results for the simply-supported beam [21].

The situation of an actual vehicle is best represented when the moving mass is suspended by a system consisting of a spring and a dashpot. The case of a beam traversed by a sprung mass has been considered assuming that the instantaneous dynamic deflection curve is proportional to the static curve due to the load in the corresponding instantaneous position [21]. The case of an orthotropic plate traversed by a sprung mass along a straight path parallel to two sides of the plate has been solved analytically [25].

The case of a moving mass partially sprung and unsprung in contact with a structure has been treated [29]. It was assumed that the static and dynamic deflection curves were instantaneously proportional. The same problem has been analyzed on the basis of a simplifying assumption: that the dynamic deflection is proportional to the first normal mode of vibration of the simply-supported beam [4].

The finite element method was first used in the 1960s [9, 30, 33]. The structures were treated as an assemblage of beam finite elements with lumped masses. A stiffness formulation for the equations of movement was used for single three-span continuous beams [9]. The moving load consisted of a sprung mass and an unsprung mass. A numerical step-by-step integration method was used to solve the equations. The results showed the influence of the mass ratio, of the time required for the load to cross the beam, and of the stiffness of the suspension on structural response. Cantilever beams under a massless moving load were analyzed [30] using a flexibility formulation of the equations of motion; these were integrated by the modal superposition method. One- and three-span continuous beams and cantilever beams were analyzed using a flexibility approach [33]. A three-axle vehicle and a nonlinear spring for the suspension were used. The equations of motion were integrated numerically step-by-step.

For a thorough treatment of the analytical methods used for problems of moving loads with and without mass in both structures and solids, see the excellent book by Frýba [10].

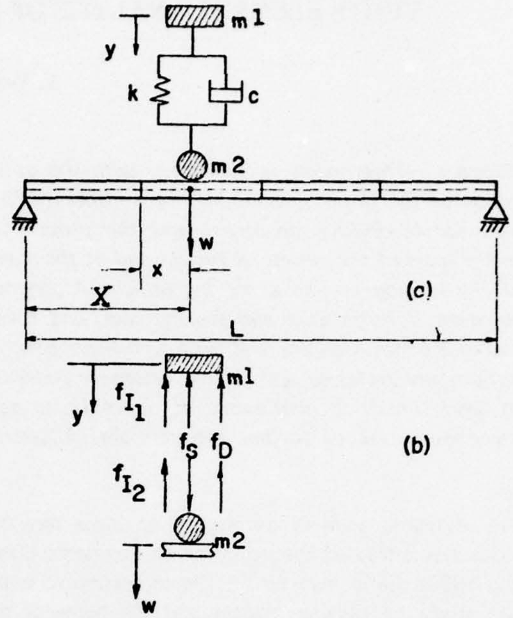


**Figure 1. An Idealized Vehicle/Structure System**

## FORMULATION AND METHODS OF SOLUTION

Consider an idealized vehicle represented by an unsprung mass in contact with a structure supporting a sprung mass. The suspension of the sprung mass consists of a spring and a dashpot. The structure, for example, a simply-supported beam, is modeled as an assemblage of finite elements. Figure 1a is the idealized vehicle and the structure. Figure 1b is a free-body diagram of the unsprung mass ($m_2$) and the sprung masses ($m_1$) and the forces acting on them.

The notation of Figure 1b is used in the following equations.

relative deflection of $m_1$ and $m_2$:

$$\Delta = y - w \tag{1}$$

spring force: $$f_S = k\Delta = k(y - w) \tag{2}$$

dashpot force: $$f_D = c\dot{\Delta} = c(\dot{y} - \dot{w}) \tag{3}$$

dynamic equilibrium of mass $m_1$:

$$m_1\ddot{y} + c(\dot{y} - \dot{w}) + k(y - w) = 0 \tag{4}$$

dynamic equilibrium of mass $m_2$ and structure:

$$\underset{\sim}{m}\,\ddot{\underset{\sim}{d}} + \underset{\sim}{c}\,\dot{\underset{\sim}{d}} + \underset{\sim}{k}\,\underset{\sim}{d} = \underset{\sim}{N}^t f_0 \tag{5}$$

In the equations $\underset{\sim}{m}$ is the structural mass matrix, $\underset{\sim}{c}$ is the damping matrix, $\underset{\sim}{k}$ is the stiffness matrix, $\underset{\sim}{d}$ is the vector of structure nodal displacements, and $\underset{\sim}{N}^t$ is a vector with zero entries except those corresponding to the nodal displacements of the loaded element (the element in which the load is positioned). These nonzero entries are the interpolation functions for external loading of the loaded element and are computed at the point where the load is acting.

The force $f_O$ acting in the loaded element is given in equation (6).

$$f_0 = (m_1 + m_2)\,g - f_{I_2} + f_S + f_D \tag{6}$$

Substitute in equation (6) $f_{I_2} = -m\ddot{w}$ for the inertia force of $m_2$ and equations (2) and (3) for the spring and damping forces respectively to obtain equation (7).

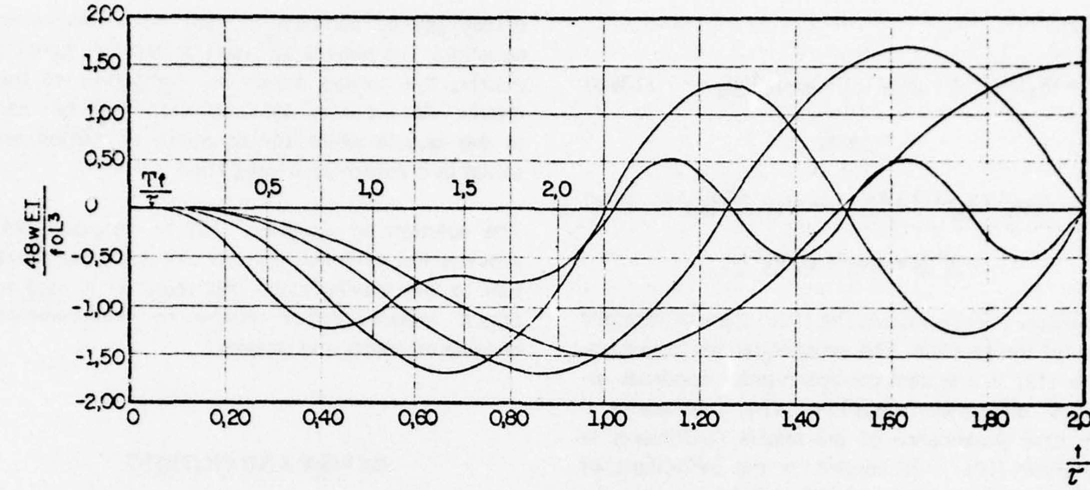


**Figure 2. Central Deflection of a Simply-Supported Beam Traversed by a Moving Load with Constant Velocity and No Damping**

$$\underset{\sim}{m}\,\ddot{\underset{\sim}{d}} + \underset{\sim}{c}\,\dot{\underset{\sim}{d}} + \underset{\sim}{k}\,\underset{\sim}{d} =$$

$$\underset{\sim}{N}^t\,[(m_1 + m_2)g - m_2\,\ddot{w} + k(y - w) + c(\dot{y} - \dot{w})] \tag{7}$$

The time derivatives of w(x, t) are given by

$$\dot{w}\,(x, t) = \frac{\partial w}{\partial x}\,\dot{x} + \frac{\partial w}{\partial t} \tag{7a}$$

$$\dot{w}\,(x, t) = \frac{\partial^2 w}{\partial x^2}\,\dot{x}^2 + 2\,\frac{\partial^2 w}{\partial x \partial t} + \frac{\partial w}{\partial x}\,\ddot{x} + \frac{\partial^2 w}{\partial t^2} \tag{7b}$$

The function w (x, t) is interpolated from the nodal displacements through the interpolation functions $\underset{\sim}{N}$ as

$$w = \underset{\sim}{N}\,\underset{\sim}{d} \tag{8}$$

Substitute equation (8) into equation (7). Note that $\underset{\sim}{N}$ is only space dependent; $\underset{\sim}{d}$ is time dependent.

$$\frac{\partial^2 w}{\partial x^2} = \underset{\sim}{N}_{,xx}\,\underset{\sim}{d} \qquad \frac{\partial^2 w}{\partial x \partial t} = \underset{\sim}{N}_{,x}\,\dot{\underset{\sim}{d}} \tag{9a, b}$$

$$\frac{\partial w}{\partial x} = N_{,x}\,d \qquad \frac{\partial^2 w}{\partial t^2} = \underset{\sim}{N}\,\ddot{\underset{\sim}{d}} \tag{9c, d}$$

The position of the vehicle (Fig. 1a) moving with constant acceleration in the loaded element is given by equation (10a).

$$x = v_o\,t + \frac{1}{2}\,a_o t^2 \tag{10a}$$

From equation (10a)

$$\dot{x} = v_o + a_o t;\ \ddot{x} = a_o \tag{10b, c}$$

Equations (9) and (10) are substituted into equations (7a) and (7b) to obtain

$$\dot{w} = (v_o + a_o t)\underset{\sim}{N}_{,x}\,\underset{\sim}{d} + \underset{\sim}{N}\,\dot{\underset{\sim}{d}} \tag{11a}$$

$$\ddot{w} = (v_o + a_o t)^2\,\underset{\sim}{N}_{,xx}\,\underset{\sim}{d} + 2(v_o + a_o t)\underset{\sim}{N}_{,x}\,\dot{\underset{\sim}{d}} + a_o\underset{\sim}{N}_{,x}\,\underset{\sim}{d} + \underset{\sim}{N}\,\ddot{\underset{\sim}{d}} \tag{11b}$$

Introduce in equations (4) and (8) $\dot{w}$ and $\ddot{w}$ from equations (11a) and (11b) to obtain the matrix equation.

$$\left[\begin{array}{c|c} \underset{\sim}{m} + \underset{\sim}{m}^* & \underset{\sim}{o} \\ \hline \underset{\sim}{o} & m_1 \end{array}\right] \left\{\begin{array}{c} \ddot{\underset{\sim}{d}} \\ \hline \ddot{y} \end{array}\right\} + \left[\begin{array}{c|c} \underset{\sim}{c} + \underset{\sim}{c}^* & -c\,\underset{\sim}{N}^t \\ \hline -c\,\underset{\sim}{N} & c \end{array}\right] \left\{\begin{array}{c} \dot{\underset{\sim}{d}} \\ \hline \dot{y} \end{array}\right\} + \tag{12}$$

$$+ \left[\begin{array}{c|c} \underset{\sim}{k} + \underset{\sim}{k}^* & -k\,\underset{\sim}{N}^t \\ \hline -c\,(v_o + a_o t)\underset{\sim}{N}_{,x} - k\,\underset{\sim}{N} & k \end{array}\right] \left\{\begin{array}{c} \underset{\sim}{d} \\ y \end{array}\right\} = \left[\begin{array}{c} (m_1 + m_2)g\underset{\sim}{N}^t \\ \hline o \end{array}\right]$$

where

$$\utilde{m}^* = m_2 N^t N;\ c^* = 2m_2 (v_o + a_o t)\utilde{N}^t \utilde{N}_{,x} + \qquad (13a,b)$$

$$C\, N^t N$$

$$\utilde{k}^* = m_2 (v_o + a_o t^2)^2\, \utilde{N}^t \utilde{N}_{,xx} + m_2 a_o \utilde{N}^t\, \utilde{N}_{,x} + \qquad (13c)$$

$$k\, \utilde{N}^t\, \utilde{N} + c(v_o + a_o t)\utilde{N}^t\, \utilde{N}_{,x}$$

Equation (12) represents the finite element formulation of the problem. The set of equations from equation (12) is a system of second-order nonlinear ordinary differential equations. The nonlinearity -- the time dependence of the matrix coefficients in equation (12) -- is implied in the definitions of equation (13). In fact $\utilde{m}^*$, $\utilde{c}^*$, and $\utilde{k}^*$ are time dependent through t and x given by equation (10a).

The case of a moving massless force is obtained by setting $(m_1 + m_2)g = f_o$, $k = 0$, and $c = 0$ in equation (12).

$$\utilde{m}\,\ddot{\utilde{d}} + \utilde{c}\,\dot{\utilde{d}} + \utilde{k}\,\utilde{d} = \utilde{f} = \utilde{N}^t f_o \qquad (14)$$

Equation (14) is a system of second-order linear differential equations.

It is pertinent to comment on the hierarchy of the approximations involved in the interpolation functions of the finite element method. The highest hierarchy, called the consistent approximation, corresponds to using the same interpolation functions for the stiffness matrix, the mass matrix, and the load. In the case of beam elements the interpolation functions are the well known cubic Hermition polynomials. A lower hierarchy, or lumped approximation, is obtained when the interpolation functions for mass and load are of lower order than those for stiffness; the functions for the load are usually linear, and those for mass are constant.

The system of nonlinear equations shown in equation (12) is generally solved by step-by-step integration methods [6]. For the case of the moving load without mass in which the system of equations shown in equation (14) is linear, the modal superposition method or a step-by-step integration method can be used. When the modal superposition method is used, structural damping can be handled in either of two ways [6]. One involves the introduction of percentages of damping in each modal decoupled equation. The second considers a Rayleigh damping matrix; the normal modes are orthogonal to this matrix. An arbitrary damping matrix can be used in the case in which the equations of motion are solved by a step-by-step integration method.

The solution of equation (12) or equation (14) provides the dynamic response of the structural system to the moving load. This response is used to obtain impact factors relative to displacements, bending moments, and stresses.

## REVIEW AND CRITIQUE

A lumped approximation method has been used to obtain general solutions for equation (14) for simply-supported, continuous, and cantilever beams, as well as orthogonal rigid frames traversed by a constant velocity moving force without mass [31]. Equation (14) has also been solved -- using a consistent approximation -- for simply-supported beams and plates for a constant velocity and a constant *acceleration moving* force without mass [35]. A plate finite element was used [5]. The modal superposition method was used to solve equation (14) [5, 35]. A solution of equation (12) for the case of an unsprung mass traversing a simply-supported beam and a plate with constant velocity and acceleration has also been published [5]. Equation (14) has also been solved for orthogonal bridge grids under a constant velocity force using the lumped approximation [19].

The consistent approximation and the Wilson method have been used [8] to solve equation (12) for a simply-supported beam traversed by an idealized vehicle (see Fig. 1a). Values for the following ratios were considered: vehicle mass/beam mass; vehicle stiffness (k, Fig. 1)/beam stiffness; and vehicle damping (c, Fig. 1)/ beam damping. Equation (14) has also been solved for a moving force with constant velocity and acceleration by the same step-by-step integration method [8]. The values obtained for the dynamic response of the central deflection of a simply-supported beam traversed by a constant velocity moving force [8, 31, 35] is equal to analytical results of Warburton [32]. The dynamic response is shown in Figure 2 for various values of

$T_f/\tau$, where $T_f$ is the fundamental period of the beam and $\tau$ is the traversing time. The impact factors are given in Table 1.

The same dynamic response considering a Rayleigh damping matrix has been obtained [8] and is shown in Figure 3. The corresponding impact factors are given in Table 1. When structural damping is considered, the impact factor decreases about 20 percent.

The dynamic response of the central deflection of a simply-supported beam traversed by an idealized vehicle with $m_m/m_b = 1,0$ ($m_m = m_1 + m_2$ = moving mass and $m_b$ = beam mass) and $m_2/m_1 = 0.25$ are shown in Figure 4 for the constant velocity case and in Figure 5 for the constant acceleration case [8]. Table 2 shows the impact factors for various values of $m_m/m_b$ and $T_f/\tau$ for the unsprung ($m_m$) mass and the idealized vehicle with the same total mass

Table 1. Impact Factors for the Central Deflection of a Simply-Supported Beam Traversed by a Force without Mass

| $T_f/\tau$ | UNDAMPED | | | | DAMPED |
|---|---|---|---|---|---|
| | Exact | Venancio-Filho [31] | Yoshida [35] | Falabella * [8] | Falabella * [8] |
| 2.0 | 1.55 | 1.53 | 1.540 | 1.547 | 1.256 |
| 1.5 | 1.70 | -- | -- | 1.703 | 1.394 |
| 1.0 | 1.71 | 1.68 | 1.700 | 1.707 | 1.435 |
| 0.5 | 1.25 | 1.24 | 1.251 | 1.258 | 1.130 |

*Time interval for step-by-step integration = $\tau/400$

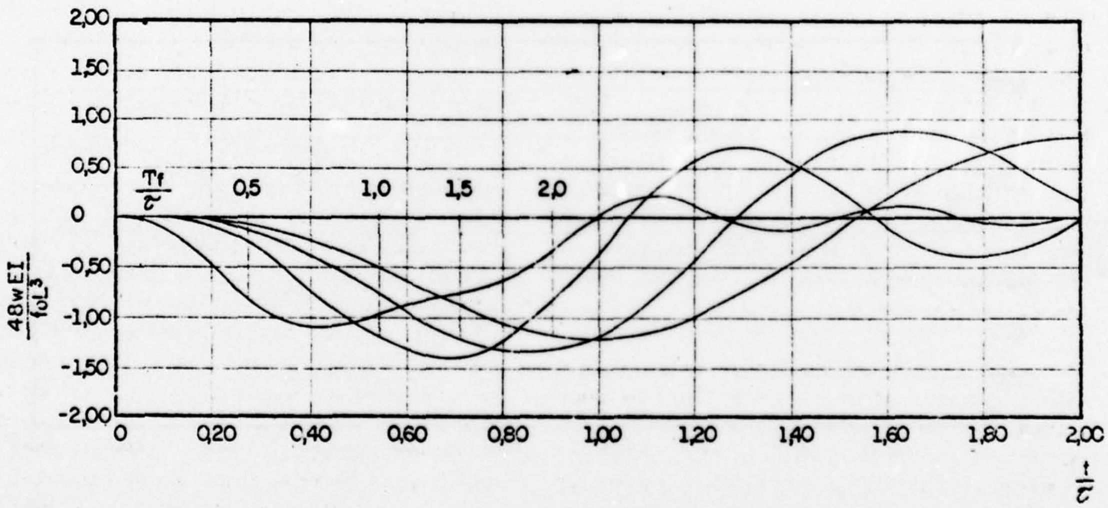


**Figure 3. Central Deflection of a Simply-Supported Beam Traversed by a Moving Load with Constant Velocity and Damping**

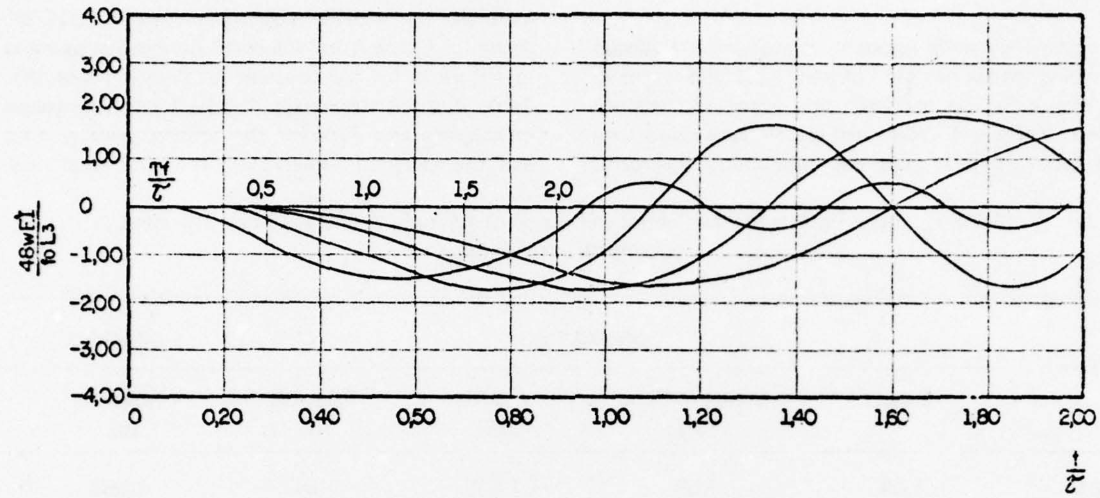


**Figure 4. Central Deflection of a Simply-Supported Beam Traversed by the Idealized Vehicle with Constant Velocity**

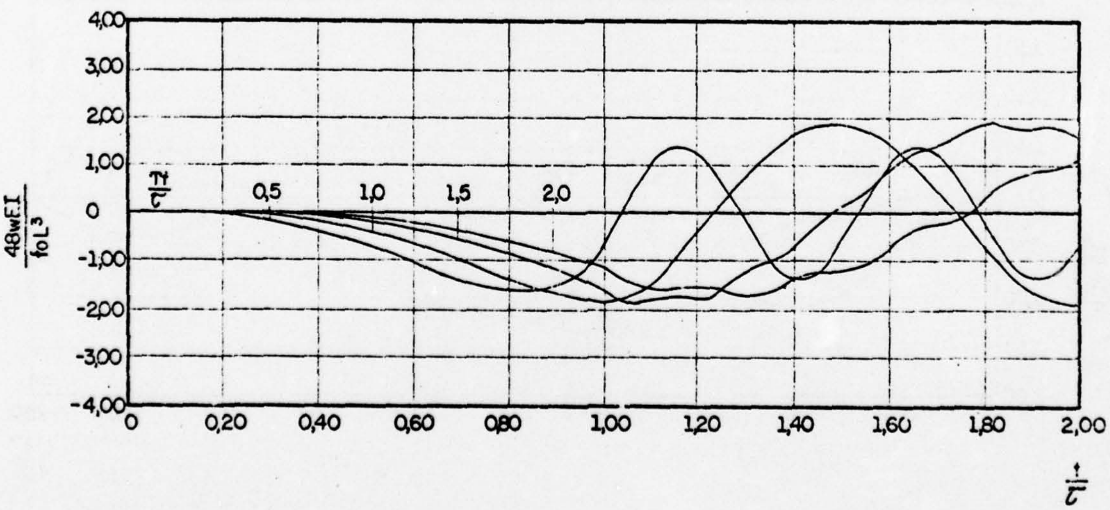


**Figure 5. Central Deflection of a Simply-Supported Beam Traversed by the Idealized Vehicle with Constant Acceleration**

Table 2. Impact Factors for the Central Deflection of a Simply-Supported Beam Traversed by a Moving Load with Mass

| $m_m/m_b$ | $T_f/\tau$ | UNSPRUNG MASS Constant Velocity | UNSPRUNG MASS Constant Acceleration | IDEALIZED VEHICLE Constant Velocity | IDEALIZED VEHICLE Constant Acceleration |
|---|---|---|---|---|---|
| 0.50 | 2.0 | 2.092 | 2.603 | 1.703 | 1.534 |
| | 1.5 | 2.253 | 2.622 | 1.901 | 1.804 |
| | 1.0 | 2.047 | 2.375 | 2.007 | 1.964 |
| | 0.5 | 1.418 | 1.320 | 1.963 | 2.057 |
| 1.00 | 2.0 | 2.643 | 3.864 | 1.746 | 1.725 |
| | 1.5 | 2.686 | 3.877 | 1.894 | 1.891 |
| | 1.0 | 2.493 | 3.329 | 1.865 | 1.926 |
| | 0.5 | 1.575 | 1.631 | 1.607 | 1.695 |
| 2.00 | 2.0 | 3.565 | 6.040 | 1.908 | 2.227 |
| | 1.5 | 3.668 | 6.107 | 2.052 | 2.260 |
| | 1.0 | 3.397 | 5.472 | 1.898 | 2.169 |
| | 0.5 | 1.873 | 2.580 | 1.480 | 1.529 |
| 4.72 | 2.0 | 5.062 | 14.527 | 2.466 | 3.578 |
| | 1.5 | 5.407 | 13.881 | 2.509 | 3.580 |
| | 1.0 | 5.252 | 11.017 | 2.325 | 3.066 |
| | 0.5 | 3.117 | 5.859 | 1.542 | 1.697 |

$(m_m = m_1 + m_2)$ and $m_2/m_1 = 0.25$. The worst case is that of the unsprung mass, constant acceleration, and greater value of $m_m/m_b$.

Equation (14) has been solved for cantilever beams traversed by a moving force with constant velocity [18]. The consistent approximation was used. The results were in good agreement with others [20].

The consistent formulation was used to solve equation (14) by the modal superposition method for beams and plates traversed by a moving force with constant velocity and acceleration [15]. The plate finite element was used [5]. This work [15] considered an arbitrary moving load pattern for the case of plates.

The strip finite element method and consistent approximation have been used to analyze the dynamic response of slabs traversed by the idealized vehicle shown in Figure 1. The contribution of the mass of the moving vehicle to the mass of the total system (structure and vehicle) is not taken into account. Hence the system of linear equations as shown in equation (14) was formulated. Vehicle inertia, damping, and spring forces were subsequently introduced in the modal equations of the structure. These nonlinear equations were solved by the Runge-Kutta method.

The techniques of the finite element method and structural dynamics allow calculation of the dynamic response of arbitrary structures to moving loads with and without mass. Areas deserving further research include nonlinear structural behavior, both geometrical and physical; response of suspended structures; and a more realistic representation of the vehicle.

## ACKNOWLEDGEMENT

The author acknowledges the assistance of Professor P.J. Fang, who read the manuscript and provided bibliographic material.

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# BOOK REVIEWS

## NUCLEAR EXPLOSIONS AND EARTHQUAKES
### The Parted Veil

B.A. Bolt
W.H. Freeman and Company, San Francisco (1976)
$12.00

Most scientists and engineers, indeed a large percentage of the general public, are aware that there is a Limited Test Ban Treaty permitting only underground tests of thermonuclear devices. We are also aware that the ultimate goal is a comprehensive treaty banning nuclear explosions by all countries which are or will become members of the nuclear club. Many of the reasons why it is so difficult to reach such an international agreement are not generally known. In this book, Professor Bolt has drawn on his extensive knowledge and experience to answer some of these questions.

Professor Bolt writes that his book is "part detective story and part scientific and social history." This is true. The reviewer feels the book is an extremely informative discussion of nuclear explosions and seismology written from the historical, social (positive and negative aspects), scientific, and political viewpoints. The author is objective in his treatment. The book is semitechnical in nature thereby making it of interest to a large number of readers.

The book contains eleven chapters and six appendices, plus a very interesting chronology of related nuclear, seismological and political events over a thirty year period beginning with the first atomic explosion in 1945. At the heart of the book is the evolution of the natural interest of seismologists in nuclear events and the impetus for expanding seismological research to cope with the problem of detecting nuclear explosions and separating them from natural earthquakes. The author begins with an historical treatment of nuclear development and leads into a discussion of the amplification of scientific knowledge to problems of surveillance, detection and discrimination with respect to natural and manmade events. Along the way the environmental hazards, the possible benefits, and the political consequences from nuclear explosions are explored. There is even a chapter on how to avoid detection of a nuclear test. Throughout the book enough basic technical information is included so that the reader needs no other references for full comprehension.

This book is exceptionally well written. It is on a timely subject of interest to the shock and vibration community. The reviewer highly recommends it as good reading.

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## MEASUREMENT AND PREDICTION OF STRUCTURAL AND BIODYNAMIC CRASH-IMPACT RESPONSE

K. Saczalski
ASME, New York, NY (1976)

This volume is one of a series of special publications of the American Society of Mechanical Engineers. It contains a collection of ten papers presented at a symposium on crashworthiness sponsored by the Structures and Materials Committee of the Aerospace Division of ASME at their 1976 Winter Annual Meeting in New York. Crashworthiness is defined by the editors of this volume as that branch of technology that "...deals with the understanding of how structural and biodynamic systems respond when subjected to crash impact environments." The material presented is in one of two categories: methods for vehicle structure crashworthiness prediction and evaluation and biodynamic response measurement

and prediction techniques.

The first paper presents a brief overview of the symposium and discusses some of the significant factors and interrelations among several areas of research associated with crash-impact problems. These areas include vehicle structure crashworthiness, effectiveness of human protection systems, and human injury tolerance. The second paper is concerned with scale model experiments as an alternative to purely analytical procedures for verification and design of crashworthy structures. The use of experimental techniques to obtain nonlinear load-deflection characteristics and the effects of structural modifications under impact loadings are discussed. The cost-effectiveness of scale model testing as compared with full-scale experiments is mentioned. Costs are not compared with those involved with analytical approaches.

The four succeeding papers comprising the first part of this volume are associated with numerical analysis techniques for predicting structural crash-impact response. The following are included:

- a survey and critical review of existing large-scale computer programs for deterministic crash analyses
- details associated with the formulation, solution strategy, and computer implementation of a particular structural crash simulator that incorporates a substructuring approach to alleviate the problem of solving large order systems of equations
- a progress report of an ongoing study that will compare results of full-scale crash tests with a "hybrid" analysis simulator (lumped masses and nonlinear springs)
- the use of simplified models (two mass) to investigate optimum performance characteristics of such automobile components as occupant displacement, compartment displacement, and peak forces

The remaining four papers deal with biodynamic response measurement and prediction techniques. Included are:

- a review of models used to measure and predict spine, thorax, and whole-body occupant response
- a description of criteria for head injuries, and methods used to evaluate the effectiveness of protective head gear
- the development of a three-dimensional head-neck analytical model for shock-impact response predictions
- a numerical prediction technique for head-helmet system response involving variable contact and separation, and an overview of analytical procedures for treating the contact conditions of arbitrarily-shaped bodies and their subsequent separation

It should be noted that the authors of eight of the ten papers contributed similar material to the proceedings of a previous symposium -- Aircraft Crashworthiness, edited by K. Saczalski et al., Univ. Press of Virginia, 1975. The symposium was restricted to crashworthiness of aircraft, but it is more extensive in scope than the ASME publication. Nevertheless, the material in the volume under review -- a combination survey and reports of work in progress -- can be both meaningful for those with a stake in the area and for those researchers requiring a concentrated up-date of this emerging technology.

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## DEVELOPMENTS IN MECHANICS VOLUME 8

Proceedings of the 14th Midwestern Mechanics Conference

This book contains the papers presented at the 14th Midwestern Mechanics Conference, which was held at the University of Oklahoma, Norman, Oklahoma, from March 24 to 26, 1975. This conference, begun in 1961, is a merger of a conference on fluid mechanics first held in 1950 and a solid mechanics conference begun in 1953. The Midwestern Mechanics Conferences is held in odd-numbered years.

The proceedings contain 26 papers in solid mechanics, nine in fluid mechanics, and three general lec-

tures. Most of the papers are analytical in nature. The topics, particularly in solid mechanics, range through most of the traditional areas -- classical dynamics, vibrations, stress analysis, elasticity, applied mathematics, and stability.

The general lectures will be most interesting to engineers involved in mechanics research; the topics cover areas of future importance as well as those with immediate application. The first lecture, by H. Ashley, is "Challenges for Mechanics in Improving the National Energy System." A lecture by D.K. Lilby discusses "New Horizons in Regional and Small Scale Meteorology." The "Applications of the Finite Element Method in Solid Mechanics, Fluid Mechanics, and Heat Transfer" was presented by R.E. Nickell.

The number of both regional and national conferences has grown in recent years. Attendance has been excellent, and policies have become flexible enough to permit publication of either an extended abstract or the complete paper, depending on the author's choice. As a result ongoing research work is accessible, and current investigations can be discussed while they are in progress by conference participants and individual researchers. In addition, conference proceedings are available to nonparticipants, so that they have also been able to communicate with individual researchers. The pressure of meeting conference publication deadlines has forced a quick review process on the organizing committee, very different from the process for technical journals.

Some excellent full-length papers have appeared in conference proceedings, and the volume herein reviewed is a good example. The reviewer believes that researchers in mechanics can benefit from including conference proceedings in their literature searches.

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## DYNAMIC PROBLEMS OF THERMOELASTICITY

W. Nowacki
Noordhoff International Publishing, Leyden, The Netherlands, 1975

This book is a translation of a book that appeared in Polish in 1966. The editors of the English edition are Francis and Hetnarski. Other than the addition of a bibliography, the book is a reasonably direct translation of the Polish version.

Thermoelasticity is concerned with the interaction of deformation and thermal fields, and combines the theory of elasticity and the theory of heat conduction. The book is a reasonably comprehensive treatise devoted to the analytical theory of dynamic thermoelastic problems. It also treats the coupling of strain, temperature, and electromagnetic effects.

The book is well written. A background in elasticity and heat conduction will be helpful to the reader. The variational theorems are clearly presented and smoothly integrated into the text. The presentation leans heavily on the pioneering research efforts of the author.

The subject matter includes the following topics:

- Fundamentals of thermoelasticity including variational theorems.
- Propagation of thermoelastic waves varying harmonically in time, including presentation of singular solutions of the thermoelastic equations.
- Propagation of thermoelastic waves due to nonperiodic sources. Approximate solutions such as perturbation responses are considered.
- Two-dimensional problems such as discs and thin plates.
- Anisotropic and piezoelectric bodies.
- Magnetothermoelasticity.

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# SHORT COURSES

## AUGUST

### STATISTICAL METHODS IN RELIABILITY

Dates: August 28 - September 1, 1978
Place: Redwood City, California
Objective: This course is designed for those engineers and scientists who are interested in applying the latest developments in statistical methods and techniques to the solution of reliability and system safety problems. The course will cover the applications of some recent developments in reliability theory, such as total time on test processes, time series analysis of failure data, software reliability, redundancy, optimization, and graphical and computer techniques for failure data analysis.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. - (202) 676-6106 or toll free (800) 424-9773.

### CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates: August 28 - September 1, 1978
Place: UCLA
Objective: This course covers the latest practical techniques of correlation and coherence analysis (ordinary, multiple, partial) for solving acoustics and vibration problems in physical systems. Procedures currently being applied to data collected from single, multiple and distributed input/output systems are explained to: classify data and systems; measure propagation times; identify source contributions; evaluate and monitor system properties, predict output responses and noise conditions; determine nonlinear and nonstationary effects; and conduct dynamics test programs.

Contact: P.O. Box 24902, Continuing Education in Engineering and Mathematics, UCLA Extension, Los Angeles, CA 90024 - (213) 825-3344/825-1295.

## SEPTEMBER

### 7TH ADVANCED NOISE AND VIBRATION COURSE

Dates: September 11-15, 1978
Place: Institute of Sound and Vibration Research, University of Southampton, UK
Objective: This course is aimed at researchers and development engineers in industry and research establishments, and people in other spheres who are associated with noise and vibration problems. The course, which is designed to refresh and cover the latest theories and techniques, initially deals with fundamentals and common ground and then offers a choice of specialist topics. The course comprises over thirty lectures including the basic subjects of acoustics, random processes, vibration theory, subjective response and aerodynamic noise which form the central core of the course. In addition, several specialist applied topics are offered, including aircraft noise, road traffic noise, industrial machinery noise, diesel engine noise, process plant noise and environmental noise and planning.

Contact: Dr. J.G. Walker or Mrs. O.G. Hyde, Institute of Sound and Vibration Research, The University, Southampton, S09 5NH, England.

### STRUCTURED PROGRAMMING AND SOFTWARE ENGINEERING

Dates: September 11-15, 1978
Place: The George Washington University
Objective: This course provides up-to-date technical knowledge of logical expression, analysis, and invention for performing and managing software architecture, design, and production. Presentations will cover principles and applications in structured programming and software engineering, including stepwise refinement, program correctness, and top-down system development.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

**GEAR NOISE**

Dates: September 12-13, 1978

Place: The Ohio State University

Objective: This seminar should be of interest to individuals responsible for the design, manufacture, and specification of gears, whether for machine tools, automobiles, process machinery or any other purpose where gear noise is a problem. Topics to be covered are noise measurement, why gears (even when perfect) make noise, gear design effects and the effects of manufacturing errors on gear noise. Methods for modeling gear systems and their housings also will be discussed.

Contact: Mr. Richard D. Frasher, Director of Continuing Education, The Ohio State University, Columbus, Ohio 43210.

**MACHINERY VIBRATION**

Dates: September 20-22, 1978

Place: Cherry Hill, New Jersey

Objective: Lectures and demonstrations on rotor-bearing dynamics, turbomachinery blading, and balancing have been scheduled for this Vibration Institute-sponsored seminar. The keynote address on the development of balancing techniques will be given on the first day along with sessions on modal analysis, oil whirl, and computer programs. Simultaneous sessions on rotor-bearing dynamics and turbomachinery blading will be held on the second and third days. The following topics are included in the rotor-bearing dynamics sessions: critical speeds, stability, fluid film bearing design and analysis, balancing sensitivity, generator rotor balancing, gas turbine balancing, and industrial balancing. The sessions on turbomachinery blading feature excitation and forced vibration of turbine stages, structural dynamic aspects of bladed disk assemblies, finite element analysis of turbomachinery blading, steam turbine availability, metallurgical aspects of blading, torsional-blading interaction, and field tests of turbogenerator sets. Each participant will receive a proceedings covering all seminar sessions and can attend any combination of sessions.

Contact: Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

## OCTOBER

**CURRENT DEVELOPMENTS IN UNDERWATER ACOUSTICS**

Dates: October 2-6, 1978

Place: University Park, Pennsylvania

Objective: This course will cover linear and nonlinear propagation of sound in the ocean, transducers, and sources of underwater noise.

Contact: Robert E. Beam, The Pennsylvania State University, Keller Conference Center, University Park, PA 16802 - (814) 865-5141.

**SONAR AND SEISMIC SIGNAL PROCESSING**

Dates: October 9-12, 1978

Place: University Park, Pennsylvania

Objective: This course is designed to provide those scientists and engineers practicing in the fields of underwater acoustics or seismic exploration an understanding of the principles and techniques used for the detection of underwater and underground signals.

Contact: Robert E. Beam, The Pennsylvania State University, Keller Conference Center, University Park, PA 16802 - (814) 865-5141.

**MACHINERY VIBRATION SEMINAR**

Dates: October 24-26, 1978

Place: MTI, Latham, New York

Objective: To cover the basic aspects of rotor-bearing system dynamics. The course will provide a fundamental understanding of rotating machinery vibrations; an awareness of available tools and techniques for the analysis and diagnosis of rotor vibration problems; and an appreciation of how these techniques are applied to correct vibration problems. Technical personnel who will benefit most from this course are those concerned with the rotor dynamics evaluation of motors, pumps, turbines, compressors, gearing, shafting, couplings, and similar mechanical equipment. The attendee should possess an engineering degree with some understanding of mechanics

of materials and vibration theory. Appropriate job functions include machinery designers; and plant, manufacturing, or service engineers.

Contact: Mr. P.E. Babson, Mktg. Mgr., Machinery Diagnostics, MTI, 968 Albany-Shaker Rd., Latham, NY 12110 - (518) 785-2371.

## NOVEMBER

### DIGITAL SIGNAL PROCESSING

Dates: November 6-10, 1978
Place: The George Washington University
Washington, D.C.

Objective: The course is designed for engineers, scientists, technical managers, and others who desire a better understanding of the theory and applications of digital signal processing. The objective of this course is to provide the participants with the essentials of the design of IIR and FIR digital filters, signal detection and estimation techniques, and the development of Fast Fourier Transform Algorithms. The applications of digital signal processing to speech processing will also be discussed. The mathematical concepts needed for understanding this course will be developed during the presentation.

Contact: Continuing Engineering Education Program, George Washington University, Washington, D.C. 20052 - (202) 676-6106 or toll free (800) 424-9773.

### VIBRATION AND SHOCK TESTING

Dates: November 6-10, 1978
Place: Washington, D.C.

Objective: Lectures are combined with physical demonstrations: how structures behave when mechanically excited, how input and response forces and motions are sensed by pickups, how these electrical signals are read out and evaluated, also how measurement systems are calibrated. The relative merits of various types of shakers and shock machines are considered. Controls for sinusoidal and random vibration tests are discussed.

Contact: Wayne Tustin, Tustin Institute of Tech., Inc., 22 East Los Olivos St., Santa Barbara, CA 93105 - (805) 963-1124.

### STRUCTURAL ANALYSIS SHORT COURSES

The following short courses in structural analysis are being offered by Schaeffer Analysis in September and October of 1978 in Boston, Massachusetts.

NASTRAN related courses

- Static and Normal Modes Analysis Using NASTRAN
  September 18-22, 1978
- Dynamic and Nonlinear Analysis Using NASTRAN
  September 25-28, 1978
- DMAP and Substructural Analysis Using NASTRAN
  October 16-19, 1978

Finite Element Modelling

- Modern Methods in Finite Element Modelling
  September 11-15, 1978

Composite Materials

- Structural Applications of Composite Materials
  October 23-26, 1978

Contact: Schaeffer Analysis, Kendall Hill Road, Mont Vernon, New Hampshire 03057 - (603) 673-3070.

# NEWS BRIEFS

news on current and Future Shock and Vibration activities and events

## STRUCTURAL MECHANICS SOFTWARE SERIES VOLUME II

The second volume of the Structural Mechanics Software Series, edited by N. Perrone and W.D. Pilkey, continues to provide information to the technical community on structural analysis and design computer programs, including reviews of available programs of interest to structural engineers. The comprehensive summaries and state-of-the-art surveys this time include bridge rating systems, solid rocket nozzles, European finite element programs, pressure vessels, and cantilever retaining wall design. The programs added to the program library are SAP V, UCIN, WHAMS, TABS 77, DISK, TWIST, and GRILL. Once again, the editors have put together a book that presents a balance between short, but comprehensive, critical reviews of available programs, and complete documentation of a few carefully selected programs, which are available for easy access on nationwide networks.

The second volume is available now from the University Press of Virginia, Box 3608, University Station, Charlottesville, Virginia 22903, for $25. Volume I is also available from the same source for $25.

## CALL FOR PAPERS
### 1979 Environmental Sciences Meeting
### April 30-May 2, 1979, Seattle, Washington

The theme of this meeting is "Learning to use our Environment, -- How wise energy usage in product development provides cost and environmental benefits." The program is planned to provide the participants with a forum and an overview of the progress in the environmental sciences. Papers are being solicited by the IES Technical Department in the following categories: Testing, Evaluation, Ecology, Biosciences, Contamination Control, Energy, Education, and Management: as they apply to acoustics, shock and vibration, environmental/reliability, climatics, space simulation, solar radiation, electromagnetics, technical management, digital control, laboratory applications, waste management, air/water pollution, pollution control/monitoring - methods and control, socio-economic impact, environmental legislative policy/issues, land use, environmental impact assessment, medical contamination control, industrial contamination control, nuclear testing, whole-body vibration effects, environmental planning programs, college curriculum planning, in-house training programs, career education information, military specification writing, standards, energy alternatives and environmental impact.

Submit three copies of 1 page abstracts before September 15, 1978. Provide the complete title, a concise presentation of the paper, and the conclusions or results. The letter should provide the author's biographical sketch, affiliation, address, and phone number. Identify the appropriate session in which your paper would best be presented.

Send abstracts to: Dr. Amiram Roffman, 1979 Technical Program Chairman, Energy Impact Associates, Inc., P.O. Box 1899, Pittsburg, PA 15230 or phone (412) 256-5640.

## CALL FOR PAPERS
### Inter-Noise 79

The eighth International Conference on Noise Control Engineering will be held in Warsaw, Poland on September 11-14, 1979. The conference will include technical sessions consisting of invited, contributed: verbal and poster form presentations in all branches of noise control activities and an exhibition of the latest equipment and instrumentation for noise control. English will be the working language. Contribution on the following topics have been selected for the technical program: community noise, aircraft and airport noise, rail transportation noise, traffic noise abatement, machinery noise reduction at the source, reduction of in-plant noise, noise control engineering in buildings, designing and planning for

industrial noise control; noise measurement, analysis and instrumentation; materials and products for noise control, international standards and legislative requirements for noise control, and construction noise.

The text of the abstract should be 400 words in length. Authors should include name, mailing address, phone number, and indicate the program topic to which the abstract is directed. Abstracts are due on December 15, 1978. Contact Professor Stefan Czarnecki, General Chairman, INTER-NOISE 79, IPPT PAN, ul. Świetokrzyska 21, 00-049 Warszawa, Poland.

## INSTITUTE OF ENVIRONMENTAL SCIENCES AWARDS THE IRWIN VIGNESS AWARD

Mr. Alex Berman of the Kaman Aerospace Corporation, Bloomfield, Connecticut, was presented the IES Irwin Vigness Award for his contribution to the science of structural dynamics by formulating Complex Dynamics Models of non standard structures and mechanics, by the judicious and creative use of testing, and for his pioneering contributions to the formulation of the system identification method.

The Irwin Vigness Award is given to the individual or author whose contribution to the field of acoustics, shock and vibration are considered outstanding. For further information contact: B.L. Peterson, Executive Director, Institute of Environmental Sciences, 940 E. Northwest Highway, Mount Prospect, IL 60056 or phone (312) 255-1561.

## NOISE-CON 79
**April 30 to May 2, 1979, Purdue University**

The conference will be sponsored by Purdue University and the Institute of Noise Control Engineering/USA. The theme of the 1979 National Conference on Noise Control Engineering is machinery noise control. Several different sessions will be held in which papers will be presented on noise from industrial machinery, engines, pumps, compressors, and home appliances. Prior to Noise-Con 79, there will be a special seminar on machinery noise control, on April 26-28, 1979. For further information on the conference or seminar, please write: NOISE-CON 79, 116 Stewart Center, Purdue University, West Lafayette, Indiana 47907 or phone (317) 749-2533.

# ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

## ABSTRACT CONTENTS

# ANALYSIS AND DESIGN

## ANALYTICAL METHODS

**78-1058**

**Synthesis of Nonlinear Mechanical Systems with Time-Optimal Condition**

J. Szadkowski

Nonlinear Vibration Problems. Polish Acad. Sci., Inst. of Fundamental Technol. Res., No. 18, pp 95-105 (1977) 9 figs, 2 refs

Key Words: Structural synthesis, Damping coefficients

This work deals with the optimal synthesis of the differential equation $\ddot{x} + (a - b\psi x^2 - c\psi \dot{x}^2)\dot{x} + dx = 0$, where a, b, $c > 0$, $d > 1$, $|\phi| \leqslant 1$, $|\psi| \leqslant 1$. The problem of synthesis consists in the determination of the damping nonlinearity which is optimal with regard the "speed" of tending of the solutions to the trivial solution.

**78-1059**

**Numerical Treatment of Eigenvalue Problems for Differential Equations with Discontinuous Coefficients**

I. Babuska and J.E. Osborn

Inst. for Physical Science and Tech., Maryland Univ., College Park, MD, Rept. No. ORO-3443-63; BN-853, 119 pp (Apr 1977)
N78-13816

Key Words: Eigenvalue problems

The eigenvalues of a second-order differential equation are approximated by factoring the second order equations into a first order system and then applying the Ritz-Galerkin method to this system. Convergence results and error estimates are devised. These error estimates are based on the application of Sobolev spaces with variable order.

## NUMERICAL ANALYSIS

**78-1060**

**Numerical Study of Linear and Nonlinear String Vibrations by Means of Physical Discretization**

F.D. Auret and J.A. Snyman

Dept. of Physics, Univ. of Port Elizabeth, Port Elizabeth, Republic of South Africa, Appl. Math. Modeling, 2 (1), pp 7-17 (Mar 1978) 9 figs, 10 refs

Key Words: Strings, Flexural vibrations, Numerical analysis

To solve partial differential equations numerically, discretization of the continuous model is required and may be achieved either mathematically or physically. This paper illustrates how physical discretization of a continuous string may be accomplished by employing discrete model theory which has as its essential substance Newtonian mechanics. Typical examples of wave motion in discretized 'linear' and 'nonlinear' strings are discussed.

## OPTIMIZATION TECHNIQUES

**78-1061**

**Optimal Weighted Orthogonalization of Measured Modes**

M. Baruch and I.Y. Bar Itzhack

Technion-Israel Inst. of Tech., Haifa, Israel, AIAA J., 16 (4), pp 346-351 (Apr 1978) 5 tables, 18 refs

Key Words: Mode shapes, Optimization

A technique is described by which measured modes, which usually do not satisfy the theoretical requirement of weighted orthogonality, are forced to satisfy this condition in an optimal way. The corrected modes are closest to the measured ones in a weighted Euclidean sense. Direct and iterative methods for computing the corrected modes are shown and discussed. The stiffness matrix that complies with the required orthogonality conditions and is the closest matrix to a previously given stiffness matrix is also found.

## STABILITY ANALYSIS

**78-1062**

**On Selection of the Best Liapunov Function**

B. Radziszewski and A. Szadkowski

Nonlinear Vibration Problems. Polish Acad. Sci. Inst. of Fundamental Technol. Res., No. 18, pp 89-93 (1977) 4 refs

Key Words: Stability methods, Lyapunov's method

This paper exhibits the possibility of selecting the best Liapunov function. It also provides the suitable method which is presented on the example asymptotic stability by the Liapunov second method. The optimum selection of the Liapunov function consists here in obtaining the results in the sense of sufficiency. The theorem of asymptotic stability is given for the equation $m\ddot{x} + h\dot{x} + [c + g(t)]x = 0$. The results obtained here are compared to those described in earlier works.

## STATISTICAL METHODS

**78-1063**

**Quick Way to Predict Random Vibration Failures**

D.S. Steinberg

Singer Kearfott Co., Wayne, NJ, Mach. Des., 50 (8), pp 188-191 (Apr 6, 1978) 4 figs, 4 refs

Key Words: Diagnostic techniques, Fatigue life, Random vibration, Normal density functions

A simple method for predicting the fatigue life of a randomly vibrating part, based on Gaussian probability distribution curve, is described. In this method, structural stress is determined from physical parameters, such as natural frequency, output acceleration, and dynamic loading. These probable stress levels are then used to calculate the number of fatigue cycles required to produce failure.

## FINITE ELEMENT MODELING

(Also see Nos. 1073, 1132, 1198)

**78-1064**

**The Use of Finite Element Models in Dynamic Analysis of Offshore Structures**

J.K. Vandiver

Massachusetts Inst. of Tech., Cambridge, MA, "Finite Element Applications in Vibration Problems," M.M. Kamal and J.A. Wolf, Jr., Eds., ASME publication H00102, pp 1-18 (1978) 5 figs, 1 table, 39 refs

Key Words: Finite element techniques, Off-shore structures, Dynamic structural analysis

This paper reviews the widespread application of finite element techniques in modeling the dynamic response of offshore structures. Applications to welded steel jacket structures as well as reinforced concrete gravity structures are described. Areas of current research interest are pointed out. The detection of structural or foundation failure by measuring changes in structural natural frequencies is presented as an example of the usefulness of finite element modeling techniques.

**78-1065**

**The Finite Element Method as Applied to Mechanisms**

R.C. Winfrey

Digital Equipment Corp., Maynard, MD, "Finite Element Applications in Vibration Problems," M.M. Kamal and J.A. Wolf, Jr., Eds., ASME publication H00102, pp 19-39 (1978) 12 figs, 22 refs

Key Words: Mechanisms, Vibration response, Finite element technique

The finite element method can be applied to mechanisms having links that are allowed, analytically, to undergo elastic deformation because of both inertial and externally applied forces.

**78-1066**

**A Finite Element Method for Linear Viscous Isotropic Material Behavior (Ein Finites Elementverfahren für Linear-Viskoses-Isotropes Stoffverhalten)**

W. Krings

Inst. f. Mechanik, Ruhr Universität Bochum, Universitatsstrasse 150, D463, Bochum-Querenburg, East Germany, Z. angew Math. Mech., 57 (12), pp 707-715 (Dec 1977) 7 figs, 4 refs

(In German)

Key Words: Finite element technique, Mathematical models, Viscoelasticity

The paper shows the displacement method for linear isotropic viscoelasticity with finite elements. The problems considered are geometrically linear. A spring-dashpot-model for the deviator behavior and one for the hydrostatic behavior describes the stress-strain-relation. The formula leads to an ordinary matrix-differential-equation with constant coefficients. Creep and vibration problems can be solved with this method.

## PARAMETER IDENTIFICATION

**78-1067**

**A Methodology for Optimal Sensor Locations for**

**Identification of Dynamic Systems**
P.C. Shah and F.E. Udwadia
Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, J. Appl. Mech., Trans. ASME, 45 (1), pp 188-196 (Mar 1978) 6 figs, 8 refs

Key Words: System identification technique

The problem of optimally positioning sensors in lumped and distributed parameter dynamic systems for the purpose of system identification from time-domain input-output data is formulated and a methodology for its solution is presented. A linear relation between small perturbations in a finite-dimensional representation of the system parameters and a finite sample of observations of the system time response is used to determine approximately the covariance of the parameter estimates.

## CRITERIA, STANDARDS, AND SPECIFICATIONS

78-1068
**Regulation of Motor Vehicle Noise in Canada**
E.R. Welbourne
Transport Canada, SAE Paper No. 780385, 8 pp, 1 table, 14 refs

Key Words: Traffic noise, Noise control, Regulations

The need for motor vehicle noise regulation is briefly reviewed and the provisions of current Canadian federal standards are outlined. An assessment of the effectiveness of current regulations is made in general terms and possible future regulatory actions are discussed.

78-1069
**Motor Vehicle Noise Control Legislation in Australia**
R. Snow and R. Law
Noise Control Branch, Environment Protection Authority, Australia, SAE Paper No. 780384, 16 pp, 11 figs, 1 table

Key Words: Traffic noise, Noise reduction, Regulations

The preparation of objective legislation to control noise from motor vehicles is well advanced in Australia and enforcement has commenced in some Australian States. A design rule setting criteria for noise emissions from new vehicles was published by the Federal Department of Transport in 1972 and a revised design rule reducing the maximum permissible levels was finalized in 1976 but its implementation has been deferred. Following extensive surveys, regulations setting criteria for in-service vehicles have been prepared by the Environment Protection Authority in Victoria and it is anticipated that these criteria will be adopted by all States in Australia.

## SURVEYS AND BIBLIOGRAPHIES

78-1070
**Vibration of Overhead Transmission Lines**
R.N. Dubey
Dept. of Mech. Engrg., Univ. of Waterloo, Waterloo, Ontario, Canada, Shock Vib. Dig., 10 (4), pp 3-6 (Apr 1978) 25 refs

Key Words: Reviews, Transmission lines, Vibration response, Vibration control

This paper reviews problems associated with low-frequency vibrations of single and bundled conductors, reports on forms of instability not previously described, and describes preventive methods for galloping.

78-1071
**Impedance Methods for Machine Analysis**
M. Massoud and H. Pastorel
Mech. Engrg. Dept., Faculty of Applied Sciences, Univ. of Sherbrooke, Sherbrooke, Quebec, Canada, Shock Vib. Dig., 10 (4), pp 9-18 (Apr 1978) 2 tables, 113 refs

Key Words: Reviews, Mechanical impedance, Diagnostic techniques, Crashworthiness, Elastic waves

This paper considers current impedance analysis techniques and their applications in the design and analysis of machines. A background summary and basic definitions are followed by descriptions of current impedance measurement and testing techniques. Traditional applications are briefly surveyed. Recent applications have involved preventive maintenance, crashworthiness, acoustic radiation, and the environment. Relevant publications are cited.

78-1072
**Parametric Vibration. Part IV: Current Problems (2)**
R.A. Ibrahim
Arab Organisation for Industrialisation, Sakr Factory for Developed Industries, P.O. Box 33, Heliopolis, Cairo, Egypt, Shock Vib. Dig., 10 (4), pp 19-

47 (Apr 1978) 277 refs

Key Words: Reviews, Parametric vibration, Pendulums, Shafts, Machinery components, Hydraulic equipment, Missiles, Satellites

Many aspects of parametric vibrations have been studied. Current problems in engineering applications having to do with pendulum systems, shafts, mechanisms and machine components, hydro- and aeroelastic systems, and missiles and satellites are reviewed in this article.

**78-1073**
**Finite Element Models for Automotive Vehicle Vibrations**
M.M. Kamal and J.A. Wolf, Jr..
General Motors Res. Lab., Warren, MI, "Finite Element Applications in Vibration Problems," M.M. Kamal and J.A. Wolf, Jr., Eds., ASME publication H00102, pp 67-92 (1978) 26 figs, 1 table, 102 refs

Key Words: Automobiles, Vibration response, Finite element technique, Reviews

During the last five years, the use of finite element methods in automotive structural design analysis has increased at an explosive pace. This has been especially evident in the calculation of dynamic and vibration response for the vehicle structure. Whole vehicle analyses are now routinely performed with sophisticated graphics packages for preparing input data and scanning output results, and with substructuring and superelement methods for saving computer costs. We will examine these and other automotive applications of state-of-the-art finite element methods in this paper.

### MODAL ANALYSIS AND SYNTHESIS

**78-1074**
**Using Modal Techniques to Guide Acoustic Signature Analysis**
R.J. Allemang and W.R. Shapton
Univ. of Cincinnati, Cincinnati, OH, SAE Paper No. 780106, 12 pp, 8 figs

Key Words: Acoustic signatures, Modal analysis

The use of signature analysis to determine the acceptability of parts in a production line quality control situation is highly desirable. Specifically, the use of acoustic signature analysis is attractive due to the relaxed constraints in terms of fixturing the part in preparation for analysis. This study discusses techniques presently being investigated which rely on knowledge of the modal coefficients to direct the area of investigation.

## COMPUTER PROGRAMS

### GENERAL

**78-1075**
**NOISEMAP Computer Program Operator Manual. Addendum for Version 3.4 of NOISEMAP**
N. Reddingius
Bolt Beranek and Newman, Inc., Canoga Park, CA, Rept. No. AMRL-TR-77-75, 14 pp (Dec 1977) AD-A049 070/6GA

Key Words: Computer programs, Aircraft noise

NOISEMAP is a computerized procedure for predicting contours of equal noise exposure around airbases. It is routinely used to aid airbase planners to prevent community effectiveness of installations and for conducting environmental noise assessment studies. This technical memorandum describes the four new features incorporated into version 3.4 of the NOISEMAP program.

## ENVIRONMENTS

### ACOUSTIC

(Also see Nos. 1068, 1069, 1071, 1075, 1113, 1121, 1145, 1180)

**78-1076**
**Random and Systematic Measurement Errors in Acoustic Impedance as Determined by the Transmission Line Method**
T.L. Parrott and C.D. Smith
Langley Res. Center, NASA, Langley Station, VA.,

Rept. No. NASA-TN-D-8520; L-11231, 73 pp (Dec 1977)
N78-15848

Key Words: Acoustic impedance, Error analysis

The effect of random and systematic errors associated with the measurement of normal incidence acoustic impedance in a zero-mean-flow environment was investigated by the transmission line method. The influence of random measurement errors in the reflection coefficients and pressure minima positions was investigated by computing fractional standard deviations of the normalized impedance. Both the standard techniques of random process theory and a simplified technique were used.

**78-1077**

**Theory of Elastic Resonance Excitation by Sound Scattering**

L. Flax and L.R. Dragonette

Naval Research Lab., Washington, D.C. 20375, J. Acoust. Soc. Amer., 63 (3), pp 723-731 (Mar 1978) 7 figs, 16 refs

Key Words: Sound scattering, Submerged structures, Resonant response

The resonance formalism of nuclear-reaction theory is applied to the problem of sound scattering from submerged elastic bodies (illustrated here by circular cylinders and spheres).

**78-1078**

**Quantitative Studies of Traffic Noise Annoyance**

G.W. Cermak and C.R. von Buseck

Societal Analysis Dept., General Motors Research Lab., Warren, MI, SAE Paper No. 780390, 12 pp, 4 figs, 19 refs

Key Wores: Traffic noise, Human response

This paper describes a continuing research program on traffic noise annoyance that is being conducted by the Societal Analysis Department at the General Motors Research Laboratories. The work involves a combination of laboratory, field, and computer modeling studies. Results are intended to provide a better fundamental understanding of noise-induced annoyance. Potential applications include the evaluation of various vehicle noise reduction programs.

**78-1079**

**The Behavior of Noise Exposure Variables in an Urban Noise Survey Sample**

W.K. Connor

Tracor Sciences & Systems, Tracor, Inc., 6500 Tracor Lane, Austin, TX 78721, Noise Control Engr., 10 (1), pp 14-21 (Jan/Feb 1978) 10 figs, 8 tables, 14 refs

Key Words: Urban noise, Noise measurement

Many different descriptors have evolved for expressing noise exposure in communities. Because of the relatively high degree of correlation which can usually be demonstrated among several of these descriptors, it has been argued that at least some of them are redundant. In an analysis of a diverse sample of community noise in a medium-sized American city, the author shows that while many noise parameters are well correlated, their relationships differ substantially according to certain variables.

**78-1080**

**Noise Prediction of Heavy Vehicles in Non-Uniform Traffic Flow**

C. Sparkes and J.B. Large

Inst. of Sound and Vibration Res., Univ. of Southampton, UK, SAE Paper No. 780388, 12 pp, 6 figs, 11 refs

Key Words: Traffic noise, Noise prediction

A technique has been developed to predict the noise generated by queues of vehicles accelerating directly across a controlled intersection, and comparisons have been made with field measurements. Noise profiles and motion characteristics have been obtained for decelerating vehicles at a controlled intersection, and a computer simulation model has been developed to investigate the effect of sampling rate in the statistical analysis of the noise generated by accelerating heavy vehicles.

**78-1081**

**Measurement of Truck and Vehicle Noise**

M.J. Crocker and J.W. Sullivan

Ray W. Herrick Labs, School of Mech. Engrg., Purdue Univ., West Lafayette, IN, SAE Paper No. 780387, 20 pp, 21 figs, 2 tables, 41 refs

Key Words: Traffic noise, Trucks, Noise measurement, Measurement techniques

This paper reviews general methods of identifying noise sources in machinery and in particular it describes in detail two methods which have been studied by the authors on a truck: near field measurements and the coherence tech-

nique. The results of these two methods are compared with results of a third method in which the same truck with different sources wrapped and then sequentially exposed was driven past a microphone using the SAE J366b test. The paper also reviews two different stationary indoor standard tests which have been investigated: the reduced drive-by simulation method, and the sound power method. These tests could be used to supplement (or replace) the standard SAE J366b drive-by test in some cases. Comparisons are made of data from the two tests developed and the SAE J366b drive-by data for the same truck.

**78-1082**

**A Method for Determining the Equivalent Level $L_{eq}$**

R. Makarewicz
Chair of Acoustics, A. Mickiewicz Univ., Poznan, Poland, Archives of Acoustics, Polish Acad. Sci., 2 (2), pp 83-94 (1977) 4 figs, 29 refs

Key Words: Traffic noise, Equivalent sound levels

The constantly growing traffic noise caused, among others, by the rapid development of motorization, is a considerable menace to the human environment. From the view point of acoustics the rating scale generally used to evaluate the environment is the equivalent level $L_{eq}$. In this paper the relationships between such parameters as the traffic flow, the speed and sound power of individual vehicles, and parameters describing the paths of the moving noise sources are derived.

**78-1083**

**Prediction of In-Flight Exhaust Noise for Turbojet and Turbofan Engines**

J.R. Stone
Lewis Res. Center, NASA, Cleveland, OH, Noise Control Engr., 10 (1), pp 40-46 (Jan/Feb 1978) 12 figs, 22 refs

Key Words: Aircraft noise, Noise prediction

A method for a reasonably accurate prediction of static and in-flight jet engine exhaust noise is described. It is achieved by taking the multiple-source nature of the problem into account.

**78-1084**

**The Location of the Ground Focus Line Produced by a Supersonic Aircraft**

R. Makarewicz
Chair of Acoustics, A. Mickiewicz Univ., Poznan, Poland, Archives of Acoustics, Polish Acad. Sci., 2 (3), pp 167-176 (1977) 8 figs, 7 refs

Key Words: Aircraft, Sonic boom

An aircraft flying at a speed higher than that of the propagation of sound produces a supersonic boom, and it has been observed that certain changes in the flight velocity or direction are accompanied by focusing the boom. In this paper procedural algorithms are presented which permit determination of the points on the Earth's surface at which this phenomenon occurs, for any maneuver and for accelerated rectilinear flight.

**78-1085**

**A Fundamental Study on External Engine Noise Propagation from Light Vehicles**

E. Abe and A. Kimura
Nissan Motor Co., Ltd., SAE Paper No. 780173, 20 pp, 36 figs, 3 refs

Key Words: Engine noise, Noise propagation, Noise reduction

In this paper, the problem of the engine noise propagation has been analyzed. A fundamental relationship between exterior noise and structural design is classified.

**78-1086**

**Silencing Noisy Machines**

S.P. Engstrom
McDowell Wellman Engrg. Co., Cleveland, OH, Mach. Des., 50 (2), pp 84-89 (Jan 26, 1978)

Key Words: Machinery noise, Noise source identification, Noise reduction

A method for the determination of the source of aerodynamic, hydraulic, and mechanical sounds is described along with some advice on how to muffle them with simple equipment modifications.

**78-1087**

**External Surface Noise Radiation Characteristics of Truck Diesel Engines – Their Far-Field Signatures and Factors Controlling Abatement**

T. Trella, R. Mason, and R. Karsick
Dept. of Transportation, Transportation Systems

Center, Cambridge, MA, SAE Paper No. 780174, 32 pp, 26 figs, 2 tables, 8 refs

Key Words: Diesel engines, Engine noise, Noise reduction

This paper presents the results of a comprehensive study dealing with surface noise radiation characteristics and the ranking of sources on three truck diesel engines. A special acoustic facility constructed to emphasize the acquisition of diesel engine noise data is described. Information is presented on measurement methodology and its viability for quantification of engine noise, directivity, and radiation patterns from engine surfaces. Acoustic measurements, conducted over a range of engine loads and speeds, include spectral analysis of the sound pressure field derived from a thirty-two microphone spherical array. Various noise identification techniques are explored under comparative testing to ascertain potential candidates for quantification and ranking of engine external surface radiation.

## PERIODIC

(Also see No. 1178)

### 78-1088

**Dynamic Testing of Non-Linear Materials Using Harmonic Excitation with Forces in Quadrature**

M. Rades

Polytechnic Inst., Bucharest, J. de Mecanique Appl., 22 (4), pp 593-606 (1977) 9 figs, 9 refs

Key Words: Harmonic excitation, Periodic response

This paper describes a new technique for determining the dynamic characteristics of some non-linear materials. The method is based on the analysis of the steady-state response to harmonic forces with components in quadrature of a single-degree-of-freedom system with linear hysteretic damping and cubic stiffness. Characteristic "jump" phenomena occurring in the variation of the response amplitude and phase are described using the polar diagram representation.

### 78-1089

**Subharmonic Solutions of the Duffing Equation with Large Non-Linearity**

R. Riganti

Intl. J. Nonlinear Mech., 13 (1), pp 21-31 (1978) 12 figs, 10 refs

Key Words: Forced vibration, Periodic response

The subharmonic solutions of order 1/3 of the damped Duffing equation are determined in a suitable parametric form, following the procedure recently developed and are compared with the results obtained by direct numerical integration of the same equation, carried out with respect to the time with the Runge-Kutta method. It can be deduced that the analytical solution gives satisfactory results in the approximation of the 'predominantly' subharmonic solutions of the above equation, even if the non-linearity of the system is very large.

## RANDOM

### 78-1090

**First-Passage Time for Oscillators with Nonlinear Damping**

J.B. Roberts

School of Engrg. and Applied Sciences, Univ. of Sussex, Falmer, Brighton, Sussex, UK, J. Appl. Mech., Trans. ASME, 45 (1), pp 175-180 (Mar 1978) 3 figs, 16 refs

Key Words: Random excitation, Nonlinear systems, Nonlinear damping, Failure analysis, Probability theory

A simple numerical scheme is proposed for computing the probability of first passage failure, P(T), in an interval 0-T, for oscillators with nonlinear damping. The method depends on the fact that, when the damping is light, the amplitude envelope, A(t), can be accurately approximated as a one-dimensional Markov process. Hence, estimates of P(T) are found, for both single and double-sided barriers, by solving the Fokker-Planck equation for A(t) with an appropriate absorbing barrier. The numerical solution of the Fokker-Planck equation is greatly simplified by using a discrete time random walk analog of A(t), with appropriate statistical properties. Results obtained by this method are compared with corresponding digital simulation estimates, in typical cases.

### 78-1091

**Response Envelope Statistics for Nonlinear Oscillators with Random Excitation**

W.D. Iwan and P.-T Spanos

California Inst. of Tech., Div. of Engrg. and Applied Science, Pasadena, CA, J. Appl. Mech., Trans. ASME, 45 (1), pp 170-174 (Mar 1978) 5 figs, 12 refs

Key Words: Random excitation, Nonlinear systems

An approximate analytical method is presented for determining both the stationary and nonstationary amplitude or envelope response statistics of a lightly damped and weakly nonlinear oscillator subject to Gaussian white noise.

The method is based on the solution of an equivalent linear system whose parameters are functions of the response itself. The solution derived by the approximate method is compared with that obtained by computer simulation for a Duffing oscillator.

### 78-1092

**The Effect of Random Excitation on Harmonic Oscillations of Single-Degree of Freedom System**

K. Piszczek

Nonlinear Vibration Problems. Polish Acad. Sci., Inst. of Fundamental Technol. Res., No. 18, pp 71-87 (1977) 8 figs, 1 table, 3 refs

Key Words: Random excitation, Harmonic response, Single degree of freedom systems

This work deals with the influence of random excitation as a stationary stochastic process on the excited harmonic oscillations in the resonance region of a single-degree of freedom system. A problem described by the Duffing equation has been analyzed in detail.

### 78-1093

**Spectrum Analysis of a Class of Periodically Unstationary Stochastic Impulse Processes (Spektralanalyse Einer Klasse von Periodisch Instationaren Stochastischen Impulsprozessen)**

A. Renger

Zentralinstitut f. Mathematik u. Mechanik, der Akad. der Wiss. der DDR, DDR-108 Berlin, Mohrenstrasse 39, East Germany, Z. angew. Math. Mech., 57 (12), pp 681-692 (Dec 1977) 3 figs, 11 refs (In German)

Key Words: Spectrum analysis, Random excitation, Stochastic processes

The frequency content of random impulse excitations with randomly disturbed periodic tact is described in a statistical manner. For an exact mathematical formulation it is necessary to use distributions.

## SEISMIC

(Also see Nos. 1174, 1183)

### 78-1094

**Seismic Analysis - What Goal?**

S.W. Tagart, Jr.

Nuclear Services Corp., 1700 Dell Ave., Campbell, CA 95008, Nucl. Engr. Des., 46 (2), pp 417-427 (Apr 1978) 3 figs, 10 refs

Key Words: Nuclear reactor components, Piping systems, Seismic design, Seismic analysis

The seismic analysis of nuclear components is characterized today by extensive engineering computer calculations in order to satisfy both the component standard codes such as ASME III as well as federal regulations and guides. The current nuclear seismic design procedure has evolved in a fragmented fashion and continues to change its elements as improved technology leads to changing standards and guides. The dominant trend is a monotonic increase in the overall conservatism with time causing a similar trend in costs of nuclear power plants. Ironically our improvements in the state of art are feeding a process which is eroding the very incentives that attracted us to nuclear power in the first place. This paper examines the cause of this process and suggests that what is needed is a realistic goal which appropriately addresses the overall incertainty of the seismic design process.

## SHOCK

(Also see Nos. 1071, 1083, 1103, 1115, 1148)

### 78-1095

**Matching Case Methodology for Measuring Restraint Effectiveness**

H.D. Pursel, R.W. Bryant, J.W. Scheel, and A.J. Yanik

General Motors Proving Ground, SAE Paper No. 780415, 31 pp, 41 figs, 3 refs

Key Words: Collision research (automotive), Safety restraint systems, Testing techniques

This paper describes a procedure used to evaluate the injury and fatality prevention effectiveness of automobile occupant restraint systems using field accident data. The technique involves the direct comparison of accidents involving a specific restraint with a control group of accidents with similar injury producing potential. This technique is called the Matching Case Methodology and has been initially applied by General Motors in determining air cushion effectiveness.

### 78-1096

**A Comparison of Advanced Belt Systems Regarding Their Effectiveness**

R. Weissner

Research and Dev., Volkswagenwerk AG, SAE Paper

No. 780414, 12 pp, 7 figs, 1 table, 4 refs

Key Words: Automobile seat belts, Collision research (automotive)

Belt systems are an appropriate means for realizing effective occupant protection. There are technical possibilities known, e.g. belt force limiters and preloading devices, which permit extreme safety requirements to be fulfilled by means of coordination of the belt system to the structural deformation behavior. The results presented here provide an example.

**78-1097**

**Crashworthiness Tests on Two Electric Vehicles**

B. Enserink, J.R. Hackney, and T.F. Maclaughlin

Dynamic Science, Inc., SAE Paper No. 780157, 16 pp, 21 figs, 3 tables

Key Words: Electric automobiles, Crashworthiness, Collision research (automotive), Experimental data

Crashworthiness aspects of two electric vehicles were evaluated in a modest test program. One vehicle was subjected to low-speed pendulum and barrier tests and static rollover. A second vehicle was subjected to a dynamic rollover using the procedure specified in FMVSS 208. Potential safety problems were exposed, and are addressed in the paper.

**78-1098**

**Analysis of 30 MPH Frontal Barrier Utilizing Half-Scale Metal Models**

H.A. Brownfield and D.O. Rogers

Fisher Body Div., General Motors Corp., SAE Paper No. 780366, 24 pp, 20 figs, 2 tables, 6 refs

Key Words: Collision research (automotive), Guardrails, Test models

A cost-effective early indicator of frontal barrier performance relative to government and corporate goals has been provided by half-scale metal models. These models provide direct indications of steering column kinematics and performance of specific components with respect to the windshield intrusion zone. Some indications of fuel system integrity and windshield retention evaluations have been inferred from half-scale model barrier tests. Model tests have provided early standard barrier data on vehicle crush modes and distances, barrier loads, and deceleration rates, in addition to generating data beyond what is available in standard barrier tests.

**78-1099**

**Energy Absorption by the Plastic Deformation of Body Structural Members**

M. Tani and A. Funahashi

Mitsubishi Motors Corp., SAE Paper No. 780368, 16 pp, 21 figs, 17 refs

Key Words: Energy absorption, Collision research (automotive), Crashworthiness

Vehicle energy in head-on or rear-end collisions is mainly absorbed by the front or rear longitudinal members. This paper describes the methods of calculation of crush load and the energy absorbed during the static and dynamic crush of the sheet metal members with closed-hat section together with attached flanges or walls. Calculated results were compared with experiments including full-size automobile collisions.

**78-1100**

**Crashworthy Troop Seat Testing Program**

M.J. Reilly

Boeing Vertol Co., Philadelphia, PA, Rept. No. D210-11169-1, USAAMRDL-TR-77-13, 206 pp (Nov 1977)

AD-A048 975/7GA

Key Words: Helicopter seats, Crashworthiness, Energy absorption, Crash research (aircraft)

Crashworthy troop seat designs developed under a previous contract were reviewed and design refinements were made. Component testing was planned and tests were performed. Malfunctioning components were redesigned and were retested satisfactorily. A new tubular-strut energy attenuator was developed to replace the rolling helical-wire energy attenuator which did not function properly. Crashworthy troop seats fabricated under a previous contract were modified, with new components developed during component testing.

**78-1101**

**Analysis of Structural Shock Transmission**

P. Crimi

Avco Systems Div., Wilmington, MA, J. Spacecraft Rockets, 15 (2), pp 79-84 (Mar/Apr 1978) 12 figs, 5 refs

Key Words: Shock response, Spacecraft equipment response, Spacecraft launching

An analytic procedure is developed for evaluating response of a shock-loaded structure at some point, given only the response at some other point. A specific system is analyzed and the results compared with test data. Capability of the

procedure to predict transmitted shock response is first demonstrated. An acceleration time history is then synthesized from a shock spectrum, as a sum of damped sinusoids, and used to predict shock response. Lastly, the response in the vicinity of the point of shock loading is predicted by numerical integration using a simplified model of the structure. The response so obtained is then used as input to predict transmitted shock response, demonstrating that response throughout a shock-loaded structure can be predicted without resorting to numerical simulation using a complete model.

# PHENOMENOLOGY

## COMPOSITE

**78-1102**

**Dynamic Response of Structural Panels with Polyurethane Foam Layers**

Y.K. Kim, H.B. Kingsbury, and W.R. Powers
Dept. of Mech. and Aerospace Engrg., Univ. of Delaware, Newark, DE, SAE Paper No. 780356, 16 pp, 14 figs, 5 tables, 4 refs

Key Words: Vibration absorption (materials), Laminates, Panels, Polyurethane resins

This paper investigates the dynamic response characteristics of multilayer panels containing polyurethane foam layers. Results of driving point impedance tests on multilayer beam and circular plate structures in the frequency range 200hz - 3khz are compared with corresponding results obtained using commercial damping coatings.

**78-1103**

**Shock Wave Propagation in Layered Composites**

Y. Oved, G.E. Luttwak, and Z. Rosenberg
Dept. of Aeronautical Engrg., Israel Inst. of Tech., Haifa, Israel, J. Composite Matl., 12, pp 84-96 (Jan 1978)

Key Words: Shock wave propagation, Composites, Layered materials

Stress histories in multilayered composite targets were recorded using manganin gages in plane impact powder gun experiments.

## DAMPING

(Also see Nos. 1058, 1152)

**78-1104**

**Effect of Damping on the Response of a Non-Linear System with Multiple Sine Wave Excitation**

P. Bezler and J.R. Curreri
Dept. of Applied Science, Brookhaven National Lab., Upton, NY, Rept. No. BNL-NUREG-22648; Conf-770807-14, 10 pp (1977)
N78-15500

Key Words: Nonlinear systems, Oscillators, Viscous damping, Periodic excitation

The non-linear response of the Duffing type mechanical oscillator with viscous damping and cubic type elastic hardening characteristics subjected to single sinusoidal excitation is known. The present paper is concerned with the overall maximum response of the system of a hardening spring oscillator with one degree of freedom. The maximum response as the frequencies are swept past the natural frequency region is desired and the results are compared to those that are known for the case of a simple sine wave sweep.

## FLUID

(Also see Nos. 1188, 1189)

**78-1105**

**Deterministic Stability Analysis of a Wind Loaded Structure**

P.J. Holmes and Y.K. Lin
Dept. of Theoretical and Appl. Mechanics, Cornell Univ., Ithaca, NY, J. Appl. Mech., Trans. ASME, 45 (1), pp 165-169 (Mar 1978) 6 figs, 13 refs

Key Words: Wind-induced excitation

The qualitative behavior of a pair of nonlinear differential equations arising in the study of a wind loading problem when turbulence terms are ignored is discussed. Quantitative estimates of stability boundaries are obtained. The most dangerous excitation conditions are identified.

**78-1106**

**The Small-Signal Response of Fluid Transmission Lines Including Developed Mean Flow Effects**

E.F. Moore

School of Engrg., Air Force Inst. of Tech., Wright-Patterson AFB, OH, Rept. No. AFIT/DS/AA/77D-1, 192 pp (Nov 1977)
AD-A047 763/8GA

Key Words: Transmission lines, Fluid-induced excitation, Mathematical models

Mathematical models of fluid transmission lines of arbitrary cross section were developed to describe the propagation of small signals through developed mean flow. The mean flow may be either laminar or turbulent and the fluid, either compressible or incompressible. Expressions for both the frequency and time domain dynamic responses are derived.

**78-1107**

**New Studies Improve Wave Force Spectral Calculations**

M.J. Mes

New Orleans, LA, Oil and Gas J., 76 (15), pp 58-61 (Apr 10, 1978) 4 figs, 1 table, 2 refs

Key Words: Off-shore structures, Design techniques, Water waves, Spectral energy distribution techniques, Fluid-induced excitation

Wave forces acting on an offshore structure can lead to a pronounced resonance motion which increases metal fatigue and stress on the structure, and causes larger excursions due to dynamic motion. An improved method for the calculation of short period forces and load amplification possibilities for use in the initial design of off-shore structures is described.

## SOIL

(See Nos. 1174, 1183)

# EXPERIMENTATION

## DIAGNOSTICS

(Also see Nos. 1063, 1071)

**78-1108**

**Frequency Analysis of Two Types of Simulated Acoustic Emissions**

W.J. Pardee and L.J. Graham

Science Center, Rockwell International, Thousand Oaks, CA 91360, J. Acoust. Soc. Amer., 63 (3), pp 793-799 (Mar 1978) 11 figs, 15 refs

Key Words: Diagnostic techniques, Acoustic signatures, Frequency response method

It has been suggested that the frequency spectrum of an acoustic emission burst may be a partial "signature," identifying the source. To explore this possibility in some detail, theoretical and experimental studies of two qualitatively different simulated acoustic emissions have been conducted. The first is the fracture of small (20 - 40 $\mu$m) silicon carbide grains on a steel slab. The second is the impact of a small elastic sphere of various materials on the same slab.

**78-1109**

**Integrated Machinery Inspection Program Cuts Maintenance Cost**

V.R. Dodd

Chevron U.S.A., Inc., Pascagoula, MS, Oil and Gas J., 76 (14), pp 138-145 (Apr 3, 1978) 6 figs

Key Words: Diagnostic techniques, Machinery

An integrated machinery inspection program of refinery and petrochemical plants is described. It includes: automatic machinery shut down before catastrophic failure occurs, using vibration and other instrumentation; machine surveillance and diagnostics; record keeping; design review; and quality control.

**78-1110**

**Basic Principles of the Vibro-Acoustical Diagnosis and Its Automatization (Grundprinzipien der vibroakustischen Diagnose und ihre Automatisierung)**

O.K. Postnikow

Polygrafisches Institut, Moskow, USSR, Maschinenbautechnik, 26 (12), pp 544-546 (Dec 1977) 7 refs (In German)

Key Words: Diagnostic techniques, Power transmission systems, Gear drives, Chain drives, Ball bearings, Cams

The foundations of vibroacoustical diagnostics and its automation, as well as vibration control and noise reduction of polygraphs is described. Gear drives, chain drives, ball bearings, and cam drives are discussed in detail.

**78-1111**

**Damage Analysis of Roller Chain Drives (Schadensanalyse von Rollenkettengetrieben)**

J. Müller and A. Klammert

Wilhelm-Pieck-Universität Rostock, Sektion Landtechnik, Rostock, East Germany, Maschinenbautechnik, 26 (12), pp 559-563 (Dec 1977) 27 figs, 4 refs

(In German)

Key Words: Chain drives, Roller bearings, Diagnostic techniques

The analysis of roller chain drive failure arising either from system characteristics (e.g., coupling of the chain drive and chain wheel, polygonal effects) or caused by inferior design, is described.

**78-1112**

**Acoustic Diagnosis of Trains of Toothed Gears (Akustische Diagnose von Zahnradgetrieben)**

G. Engler

Ingenieurhochschule Zwickau, Sektion Kraftfahrzeugtechnik, Zwickau, East Germany, Maschinenbautechnik, 26 (12), pp 546-549 (Dec 1977) 3 figs, 2 tables

(In German)

Key Words: Gears, Diagnostic techniques

The basis for the theoretical and practical methods in the determination of vibration and noise sources by means of polygraphic machines is described. Signal analysis is used for noise reduction and machine diagnosis. Automated methods are developed which evaluate the characteristics of the signals.

## FACILITIES

**78-1113**

**Engine Noise Testing in an Economical "Semi" Anechoic Room**

R. Gaspar, Z. Reif, and K. Sridhar

Dept. of Mech. Engrg., Univ. of Windsor, Windsor, Ontario, Canada, SAE Paper No. 780171, 12 pp, 12 figs, 17 refs

Key Words: Engine noise, Anechoic chambers

A "semi" anechoic room design has been proposed and constructed from readily available, inexpensive construction materials. To demonstrate its feasibility, noise testing was conducted using a rotary engine as the noise source.

## INSTRUMENTATION

**78-1114**

**A Novel Pressure Transducer Using Mechanical Resonance**

J. Ohga and Y. Mizushima

Musashino Electrical Communication Lab., N.T.T., Midori-cho, Musashino-shi, Tokyo, Japan, J. Dyn. Syst. Meas. and Control, Trans. ASME, 100 (1), pp 83-87 (Mar 1978) 8 figs, 5 refs

Key Words: Pressure gages, Transducers, Measuring instruments

A novel electromechanical pressure transducer, suitable for telemetering, is proposed. It transforms an absolute static pressure into a frequency signal, using acoustical resonance due to the stiffness of a fluid in a cavity and the mass of a vibrating plate.

**78-1115**

**Measurement of Wave Profiles in Shock-Loaded Solids**

R.A. Graham

Sandia Labs., Albuquerque, NM, Rept. No. SAND-77-1056C; Conf-770706-15, 33 pp (1977) 6th AIRAPT International High-Pressure Conf., July 25, 1977, Boulder, CO

N78-16373

Key Words: Shock wave propagation, Measuring instruments

The evolution of the numerous detectors which measure wave profiles in solids subjected to rapid impulsive loading was traced and principal trends were identified. Recent capabilities for the measurement of transverse or higher order motions (acceleration and velocity gradient) are described.

## SCALING AND MODELING

(See No. 1098)

## SIMULATORS

**78-1116**

**Dynamic Simulation of an Automobile Body Utilizing Finite Element and Modal Synthesis Techniques**

G.E. Townley and J.W. Klahs
Structural Dynamics Research Corp., SAE Paper No. 780364, 12 pp, 12 figs, 15 refs

Key Words: Automobile bodies, Simulation, Finite element technique, Modal synthesis

With the advent of high speed computers, dynamic simulation of an automobile body has become a reality. The present work will discuss methods to develop a body model of manageable size which will give good correlation with tests and can also be used as a practical design tool. The basic approach is to model each component as a separate entity and then combine the components into a system model, a "Building Block Approach," Finite element mesh considerations and modeling difficulties are discussed. An example of a vehicle body is presented to illustrate the approach.

## TECHNIQUES

(Also see No. 1081)

**78-1117**

**Oscillations in Squealing Disk Brakes - Analysis of Vibration Modes by Holographic Interferometry**

A. Felske, G. Hoppe, and H. Matthai
Res. and Dev. Div., Volkswagenwerk AG, Wolfsburg, West Germany, SAE Paper No. 780333, 24 pp, 32 figs, 2 tables, 27 refs

Key Words: Brakes (motion arresters), Vibration response, Noise generation, Holographic techniques, Interferometers

Analyses of squealing disk brakes generally show main frequencies from 1 to 10 kHz. On a test stand holograms exposed by time average and double-pulse techniques are recorded from various types of disk brakes. Photographs of reconstructions from those holograms display a vibration pattern in a simple topographical map of fringes, which represents contours of equal vibration amplitudes on the brake components: that would be i.e. yoke-type or fist-type callipers, brake pads and brake disk. Holographic Vibration Analysis is a useful method for looking at these small vibration amplitudes to understand different mechanisms of coupling. Also it is possible to localize vibration sources in squealing disk brakes.

**78-1118**

**Survey of Excitation Techniques Applicable to the Testing of Automotive Structures**

D. Brown, G. Carbon, and K. Ramsey
Univ. of Cincinnati, Cincinnati, OH, SAE Paper No. 770029, 20 pp, 13 figs, 5 refs

Key Words: Testing techniques, Frequency response spectrum, Motor vehicles, Modal tests

With the implementation of digital signal processing, frequency response measurements are not limited to swept sine testing. With the discrete Fourier Transform, any physically realizable signal can be used for excitation. The best technique depends on the application, available equipment, the presence of measurement noise, the linearity of the test object, and the time available in which to execute the test. In this paper a number of excitation techniques have been described. All of these techniques have advantages and disadvantages which have been described in the text of this paper.

# COMPONENTS

## SHAFTS

(Also see No. 1152)

**78-1119**

**The Optimum Design of Stepped Shafts**

C.J. Maday
Dept. of Mech. and Aerospace Engrg., North Carolina State Univ., Raleigh, NC, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication I00118, pp 187-198 (1978) 3 figs, 1 table, 3 refs

Key Words: Shafts, Variable cross section, Optimum design

Optimum stepped shaft designs are obtained through an application of Pontryagin's Minimum Principle. With the specification of critical speed and order, the designer selects a finite number of diameters or cross-sectional areas and the method is used to design a least mass or a least rotating inertia shaft. In this application, the cross-sectional area at any position along the shaft which minimizes the system Hamiltonian is selected as the shaft cross section.

**78-1120**

**Flexibility of Shafts with Abrupt Changes of Section**

N. Sanderson and R. Kitching

Dept. of Mech. Engrg., The Univ. of Manchester Inst. of Science and Tech., Manchester, UK, Intl. J. Mech. Sci., 20 (3), pp 189-199 (1978) 9 figs, 1 table, 10 refs

Key Words: Shafts, Variable cross section, Center line deflections

The calculation of deflections of shafts by simple bending theory can incur errors if it is applied where the shafts are stepped with large and abrupt changes of section. Following an experimental check, the finite element displacement method was used for an investigation into the flexural properties of such shafts, particular attention being paid to the relationship between the step geometry and the center line deflection curves.

## BEAMS, STRINGS, RODS, BARS

(Also see Nos. 1060, 1207)

**78-1121**

**Elastic Wave Propagation in an Infinite Bar of Elliptical Cross Section**

K. Sato

Dept. of Mech. Engrg., Tohoku Univ., Sendai, Japan, Bull. JSME, 21 (152), pp 203-209 (Feb 1978) 3 figs, 4 tables, 9 refs

Key Words: Bars, Elastic waves, Wave propagation

This paper studies harmonic wave propagation in an infinite elastic bar of elliptical cross section with stress-free surface by using Mathieu functions and modified Mathieu functions which are the exact solutions of the equation of motion from linear elasticity in an elliptical cylinder coordinate system. A procedure leading to the frequency equations for longitudinal, torsional and flexural waves by making use of the orthogonal properties of Mathieu functions is given. Numerical calculation for each mode is carried out.

**78-1122**

**Approximate Method for Calculating Free Vibrations of a Large-Wind-Turbine Tower Structure**

S.C. Das and B.S. Linscott

Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TM-73754; ERDA/NASA-1028/77/12, 46 pp (Dec 1977)
N78-16434

Key Words: Free vibration, Towers, Wind turbines, Mathematical models

A set of ordinary differential equations were derived for a simplified structural dynamic lumped-mass model of a typical large-wind-turbine tower structure. Dunkerley's equation was used to arrive at a solution for the fundamental natural frequencies of the tower in bending and torsion. The ERDA-NASA 100-kW wind turbine tower structure was modeled, and the fundamental frequencies were determined by the simplified method described.

**78-1123**

**Random Vibrations of a Beam on Nonlinear Spring Support**

Z. Piskorz

Nonlinear Vibration Problems. Polish Acad. Sci., Inst. of Fundamental Technol. Res., No. 18, pp 57-68 (1977) 3 refs

Key Words: Beams, Elastic foundations, Flexural vibration

This work is devoted to the analysis of bending vibration of a constant cross-section beam on a nonlinear inertialess support. The loading of the beam is treated as a time-stationary stochastic process with normal distribution and mean value equal zero. The Markov theory of multi-dimensional process is used to determine the basic probabilistic characteristic at the output of the system.

**78-1124**

**Higher Modal Dynamic Plastic Behavior of Beams Loaded Impulsively**

N. Jones and C. Guedes Soares

Dept. of Ocean Engrg., Massachusetts Inst. of Tech., Cambridge, MA 02139, Intl. J. Mech. Sci., 20 (3), pp 135-147 (1978) 10 figs, 3 tables, 12 refs

Key Words: Beams, Dynamic plasticity, Modal damping, Energy absorption

It was demonstrated in a previous study that the higher modal dynamic plastic response of beams may be a more efficient means of absorbing a given initial kinetic energy than a single modal response. Thus, the higher modal dynamic plastic response of impulsively loaded, fully clamped beams is examined herein, using various rigid perfectly plastic theoretical procedures and a numerical elastic-plastic computer code.

**78-1125**

**Parametric Resonance by Combined Frequencies of Cantilever Bars Under Periodic Axial Load by the Elastic-Joint-Method**

J.P. Rebiere and S. Sahraoui
Laboratoire de Mecanique Physique, Universite de Bordeaux 1 351 Cours de la Liberation, 33405-Talence Cedex, France, Mech. Res. Comm., 5 (1), pp 39-44 (1978) 2 figs, 9 refs

Key Words: Parametric resonance, Cantilever beams, Periodic excitation

As a part of the studies of continuous sytems under periodic axial loads the elastic-joint-method was combined with the results of HSU concerning the determination of the instabilities areas obtained by the first order asymptotic method.

**78-1126**
**The Bowed String as the Two-Terminal Oscillator**
G. Budzynski and A. Kulowski
Inst. of Telecommunication, Gdansk Tech. Univ., Archives of Acoustics, Polish Acad. Sci., 2 (2), pp 115-120 (1977) 4 figs, 15 refs

Key Words: Strings, Musical instruments, Violins

The paper presents a method of the evaluation of the shape of bowed string oscillations. The method employs the analogy between the bowed string and the electrical, two-terminal oscillator. The velocity-dependent friction force between string and bow, investigated experimentally many years ago, was applied as a stimulating function of the oscillator. The evaluated shapes and amplitudes are in good agreement with experimental results.

## BEARINGS

**78-1127**
**Tilt Stiffness and Damping of Externally Pressurized Porous Gas Journal Bearings**
N.S. Rao
Dept. of Mech. Engrg., Indian Inst. of Tech., Kharagpur, India, Wear, 47 (1), pp 31-44 (Mar 1978) 4 figs, 3 tables, 13 refs

Key Words: Gas bearings, Journal bearings, Stiffness coefficients, Damping coefficients

The dynamic behavior of an externally pressurized porous gas journal bearing is analyzed by assuming one-dimensional flow through the porous bushing. A periodic disturbance (angular displacement) about the transverse axis is imposed on the bearing and the resulting dynamic pressure distribution is determined by small perturbations of the Reynolds equation. A finite difference method is used to determine the dynamic pressure. Design data for tilt stiffness and damping as a function of squeeze number, feeding parameter, supply pressure and porosity parameter are calculated numerically using a digital computer and are presented in tables and figures.

**78-1128**
**A Pressurized Gas Squeeze Film Journal Damper**
A.K. Stiffler
Dept. of Mech. Engrg., Mississippi State Univ., Mississippi State, MS, Rept. No. NASA-CR-155533; MSSU-EIRS-ME-78-1, 89 pp (Dec 1977)
N78-15493

Key Words: Gas bearings, Squeeze film bearings, Stiffness coefficients, Damping coefficients

A lumped parameter model is developed to determine the stiffness and damping characteristics of inherently compensated gas film bearings. The model relies on the average static pressure over a one dimensional strip bearing. Results of the model are compared with known computer solutions for the distributed strip and a two dimensional square bearing.

**78-1129**
**The Dynamic Analysis of Journal Bearings Using a Finite Length Correction for Short Bearing Theory**
L.E. Barrett, P.E. Allaire, and E.J. Gunter
Dept. of Mech. and Aerospace Engrg., School of Engrg. and Applied Science, Univ. of Virginia, Charlottesville, VA, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication I00118, pp 29-41 (1978) 7 figs, 14 refs

Key Words: Transient response, Plain bearings, Squeeze film bearings

A rapid method for calculating the general nonlinear response of finite-length plain journal and squeeze film damper bearings is presented. The method incorporates a finite-length correction factor which modifies the nonlinear forces obtained from short bearing theory. The steady-state rotational, precessive squeeze, and radial squeeze forces obtained with the correction factor are compared to the forces obtained from an analytic solution of Reynolds equation using a variational approach up to L/D of 1.25. The method is no more time consuming than the short bearing analysis and is especially suited to nonlinear transient analysis of flexible rotors.

**78-1130**

**A Calculation Method and Data for the Dynamic Coefficients of Oil-Lubricated Journal Bearings**

J.W. Lund and K.K. Thomsen

Dept. of Machine Elements, The Tech. Univ. of Denmark, Lyngby, Denmark, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication I00118, pp 1-28 (1978) 2 figs, 4 tables, 13 refs

Key Words: Stiffness coefficients, Damping coefficients, Fluid-film bearings

A numerical method for calculating the stiffness and damping coefficients of oil-lubricated bearings is presented. It is a finite difference solution of Reynolds' equation, obtaining not only the steady-state pressure distribution, but also the dynamic pressures produced by a small amplitude whirl of the journal center (a first order perturbation solution). Film rupture is taken into account with the boundary to the ruptured film zone determined by an iterative procedure. An integration of the pressure yields the load carrying capacity, the four stiffness coefficients, and the four damping coefficients. Data are given in tabular form for the two-axial groove bearing, the elliptical bearing, the three-lobe bearing, and the offset cylindrical bearing.

**78-1131**

**Theoretical and Experimental Load-Deflection Studies of a Multileaf Journal Bearing**

R.J. Trippett, K.P. Oh, and S.M. Rohde

General Motors Research Lab., Warren, MI, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication I00118, pp 130-156 (1978) 11 figs, 1 table, 18 refs

Key Words: Bearings, Stiffness, Experimental data, Mathematical models

In this study the deflections of a multileaf bearing are measured under load on a rotor dynamics rig up to speeds of 40,000 rpm. The effects of rotor speed, leaf-housing attachment angle, and leaf thickness on the load-deflection characteristics of a multileaf bearing are measured. An analytical model, representative of the type of bearing tested, is developed and comparisons of predicted and measured performance are presented.

## BLADES

**78-1132**

**Finite Element Analysis of Turbomachine Blade Problems**

N.F. Rieger

Rochester Inst. of Tech., Rochester, NY, "Finite Element Applications in Vibration Problems," M.M. Kamal and J.A. Wolf, Jr., Eds., ASME publication H00102, pp 93-120 (1978) 12 figs, 1 table, 57 refs

Key Words: Turbomachinery blades, Finite element technique, Fatigue life

This paper discussed the development of finite element procedures for turbine blade fatigue analysis. Specific problems encountered in the analysis of high, low, and medium aspect ratio blades are described. The manner in which these various types of blade influence the element needed for a solution is discussed. Details of various elements developed for turbine blade problems are described for the calculation of steady stress, natural frequency, and dynamic stress. Recent developments in the analysis of bladed disk assemblies are discussed. A general procedure for fatigue analysis of blades is described, with sample applications to steam turbine blade groups.

## CYLINDERS

**78-1133**

**Longitudinal Vibrations of a Composite Isotropic Circular Cylinder**

M. Pan

$F_7$ Vidyasagar Niketan, Salt Lake, Calcutta-64, India, J. de Mécanique Appl., 22 (5), pp 795-800 (1977) 1 ref

Key Words: Circular cylinders, Longitudinal vibration, Isotropy

In the present paper an attempt has been made to find the general frequency equation of the longitudinal vibrations of a long composite circular cylinder. The cylinder has been assumed to be made of two materials, viz., one inner material and an outer material with a different type of elastic properties, i.e. a solid circular cylinder of some material is embedded within a cylindrical shell of a different material, the common boundary of the two materials being such that the displacement and stress components across it are continuous.

## DUCTS

**78-1134**

**Asymptotic Theory of Ducted Propagation**

S. Choudhary and L.B. Felsen

Dept. of Electrical Engrg., Polytechnic Inst. of New York, Brooklyn, NY 11201, J. Acoust. Soc. Amer., 63 (3), pp 661-666 (Mar 1978) 1 fig, 9 refs

Key Words: Ducts, Sound propagation

A new high-frequency asymptotic theory of propagation in ducts with continuously varying refractive index is presented. The theory is based on local wave fields with complex phase and constitutes a special application of the evanescent wave tracking theory developed by the authors. It is shown, for analytic profiles and for refractive indexes that vary only transversely to the duct direction, how the coefficients in the asymptotic expansion are evaluated explicitly. When the method is applied to parabolic and hyperbolic secant profiles for which exact solutions of the wave equation are available, the asymptotic expansions so generated agree term by term with the asymptotically expanded exact results. The method is then applied to a class of polynomial profiles for which exact results in terms of known functions are not available.

**78-1135**

**Optimum Wall Impedance for Spinning Modes: A Correlation with Mode Cut-Off Ratio**

E.J. Rice

Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TM-73862; E-9451, 17 pp (1978)

Sponsored by AIAA

N78-15853

Key Words: Ducts, Acoustic linings, Acoustic impedance

A correlating equation relating the optimum acoustic impedance for the wall lining of a circular duct to the acoustic mode cut-off ratio, is presented. The optimum impedance was correlated with cut-off ratio because the cut-off ratio appears to be the fundamental parameter governing the propagation of sound in the duct. Modes with similar cut-off ratios respond in a similar way to the acoustic liner. The correlation is a semi-empirical expression developed from an empirical modification of an equation originally derived from sound propagation theory in a thin boundary layer.

**78-1136**

**Effect of an Expansion Chamber on the Propagation of Sound in Circular Ducts**

A.I. El-Sharkawy and A.H. Nayfeh

Dept. of Engrg. Science and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Acoust. Soc. Amer., 63 (3), pp 667-674 (Mar 1978) 13 figs, 1 table, 8 refs

Key Words: Ducts, Variable cross section, Sound propagation

An analytical and experimental study is presented of sound propagation through a circular duct in the presence of an expansion chamber. Results are presented for various sound frequencies, expansion ratios, and chamber lengths. Analytical results are compared to experimental results.

**78-1137**

**Self-Excited Oscillations of Gas Flow in a Duct**

K.J. Witczak

Warsaw, Poland, Nonlinear Vibration Problems. Polish Acad. Sci., Inst. of Fundamental Technol. Res., No. 18, pp 147-206 (1977) 54 figs, 58 refs

Key Words: Ducts, Variable cross section, Self-excited vibrations, Fluid-induced excitation

Flow pattern and acoustic properties of a choked gas outflow from a circular and an annular convergent nozzle into a duct with an abrupt enlargement of its cross-section were investigated. Presented results correspond mainly to the self-excited oscillations of flow in the duct, which occur at the particular range of supply pressure.

## FRAMES, ARCHES

(See No. 1202)

## GEARS

(See No. 1112)

## LINKAGES

**78-1138**

**A Bit of Math Foils Coupling Failure**

Product Engr. (NY), 49 (4), pp 45-46 (Apr 1978) 3 figs

Key Words: Couplings

When engines and compressors are coupled, vibrations can rip the system apart unless the coupling has adequate torsional stiffness. A safe design procedure, taking into con-

sideration the mass of each component in the engine and the driven equipment as well as the torsional stiffness of the coupling elements, is described.

## MECHANICAL

**78-1139**

**Dynamic Characteristics of Planar Mechanisms with Clearances**

H. Shimojima, K. Ogawa, and K. Matsumoto

Tokyo Inst. of Tech., Meguro-ku, Tokyo, Japan, Bull. JSME, 21 (152), pp 303-316 (Feb 1978) 11 figs, 2 tables, 4 refs

Key Words: Mechanisms, Joints, Dynamic properties

Dynamic characteristics of planar mechanisms with clearances are studied with use of Lagrange's equation of motion.

## PANELS

**78-1140**

**Vibration Analysis of Corrugation-Stiffened Panels**

F.H.K. Chen and T.G. Carne

Engrg. Mechanics Dept., General Motors Research Lab., Warren, MI, SAE Paper No. 780362, 16 pp, 16 figs, 3 tables, 17 refs

Key Words: Automobile bodies, Stiffened panels, Vibration response

Automobile panels are stiffened in a variety of ways to meet engineering design criteria. Current example panels are numerous and include the roof, deck lid, hood, floor pan, etc. If lightweight, low modulus materials (e.g., aluminum, sheet molding compound) are to be considered for automobile panels, it can be anticipated that some form of stiffening will be necessary. In this paper, one particular type of stiffened panel, a two-layer panel consisting of a trapezoidally corrugated plate and a flat plate fastened together, is examined analytically and experimentally.

## PIPES AND TUBES

(Also see No. 1094)

**78-1141**

**Stability of a Pipe Carrying Time-Dependent Flowing Fluid**

G. Ahmade and M.A. Satter

Dept. of Mech. Engrg., Pahlavi Univ., Shiraz, Iran, J. Franklin Inst., 305 (1), pp 1-9 (Jan 1978) 18 refs

Key Words: Pipes (tubes), Fluid-filled containers, Vibration response

The stability of elastic pipes conveying time-dependent flowing fluids is considered. The special cases of simply supported and fixed-fixed pipes are treated. The criteria for stability of equilibrium condition of pipes are obtained when the velocity of the flow is either a deterministic periodic function or a random function of time.

## PLATES AND SHELLS

(Also see No. 1172)

**78-1142**

**Effect of Line-Discontinuity Admittance on Sound Scattered by Plate Vibration**

K.L. Chandiramani

Bolt Beranek and Newman, Inc., Cambridge, MA 02138, J. Acoust. Soc. Amer., 63 (3), pp 715-722 (Mar 1978) 6 figs, 7 refs

Key Words: Plates, Sound scattering, Discontinuity-containing media

The force and moment impedance of a line discontinuity on a plate influences the sound scattered by impingement of plate flexural waves on the line discontinuity is investigated. Effects of fluid loading are accounted for.

**78-1143**

**Large-Amplitude Vibration of Oblique Panels**

R.S. Srinivasan and S.V. Ramachandran

Dept. of Appl. Mechanics, Indian Inst. of Tech., Madras 600 036, India, J. Acoust. Soc. Amer., 63 (3), pp 800-805 (Mar 1978) 4 figs, 2 tables, 11 refs

Key Words: Free vibration, Skew plates, Variable cross section

This paper deals with the large-amplitude free vibration of skew plates having variable thickness. Two governing nonlinear differential equations in terms of the lateral deflection and "force function" are derived in the oblique coordinates.

**78-1144**

**Vibrations of Rectangular, Stepped Thickness Plates with Edges Elastically Restrained Against Rotation**

C. Filipich, P.A.A. Laura, C.E. Gianetti, and L.E. Luisoni

Inst. of Appl. Mechanics, Base Naval, Puerto Belgrano, 8111-Argentina, Intl. J. Mech. Sci., 20 (3), pp 149-158 (1978) 2 figs, 14 tables, 10 refs

Key Words: Rectangular plates, Variable cross section, Natural frequencies

The title problem is solved using simple polynomial coordinate functions which identically satisfy the boundary conditions. The Rayleigh-Ritz method is used to evaluate the natural frequencies. Numerical results are presented for several values of the parameter length to width ratio and a particular type of thickness variation.

**78-1145**

**Transient Motion of an Elastic Shell of Revolution in an Acoustic Medium**

B.S. Berger

Dept. of Mech. Engrg., Univ. of Maryland, College Park, MD, J. Appl. Mech., Trans. ASME, 45 (1), pp 149-152 (Mar 1978) 5 figs, 13 refs

Key Words: Shells of revolution, Submerged structures, Interaction: structure-fluid, Transient response, Acoustic excitation

A numerical solution for the transient vibration of an arbitrary shell of revolution, surrounded by an acoustic medium, has been formulated in terms of the conformally mapped acoustic equations, fluid shell boundary conditions and spectral representation of the shell displacements. The technique readily includes the boundary condition at infinity, internal shell structure and is exact to within those approximations implicit in the finite-difference method.

**78-1146**

**Modal Method for Free Vibration of Oval Cylindrical Shells with Simply Supported or Clamped Ends**

Y.N. Chen and J. Kempner

Dept. of Mech. and Aerospace Engrg., Polytechnic Inst. of New York, Brooklyn, NY, J. Appl. Mech., Trans. ASME, 45 (1), pp 142-148 (Mar 1978) 9 figs, 21 refs

Key Words: Cylindrical shells, Transient response, Modal analysis

The free vibration of an oval cylindrical shell of finite length was investigated with the aid of the kinematic relations of the first-order shell theory of Sanders. Transverse and inplane inertia terms were retained throughout. A method incorporating a type of eigenfunction expansion into Hamilton's principle, was developed and found to be far more convenient than a parallel Fourier analysis. In addition to the determination of the natural frequencies and deformation characteristics, attention was focused on the influence of various types of simple support and clamped end conditions.

**78-1147**

**Supersonic Flutter of Heated Circular Cylindrical Shells with Temperature-Dependent Material Properties**

U. Olsson

Volvo Flygmotor AB, Trolhattan, Sweden, AIAA J., 16 (4), pp 360-362 (Apr 1978) 3 figs, 8 refs

Key Words: Cylindrical shells, Flutter, Thermal excitation

This paper presents an analysis of the supersonic flutter of thin circular cylindrical shells. Galerkin's method is used to reduce the nonlinear shell equations to ordinary differential equations which are then solved asymptotically according to the method of Krylov-Bogoliubov. Nonstationary, axially varying shell wall temperatures are considered.

**78-1148**

**Dynamic Response of Cylindrical Shells to Concentrated Impact Load**

K. Shirakawa and K. Asano

College of Engrg., Univ. of Osaka Prefecture, Sakai, Japan, Bull. JSME, 21 (152), pp 189-195 (Feb 1978) 10 figs, 10 refs

Key Words: Cylindrical shells, Impact response (mechanical)

The dynamic response of a cylindrical shell with finite length to a concentrated impact load on its arbitrary surface is studied. The response of radial displacement and stresses is made clear through the analysis which is carried out by using the theory considering not only radial but also inplane inertia forces, and the effect of these inertia forces on the response of them is also examined. The relation between their maximum values and the ratio of length to radius of shell is shown.

**78-1149**

**Earthquake Simulator Studies of Cylindrical Tanks**

D.P. Clough and R.W. Clough
Div. of Structural Engrg. and Structural Mech., Dept. of Civil Engrg., College of Engrg., Univ. of California, Berkeley, CA 94720, Nucl. Engr. Des., 46 (2), pp 367-380 (Apr 1978) 9 figs, 21 refs

Key Words: Tanks (storage), Cylindrical shells, Fluid-filled containers, Seismic design, Experimental data, Model testing

An experimental investigation on the seismic response of ground-supported, cylindrical metal tanks is described. The aluminum scale model discussed here, 12 ft in diameter and 6 ft high, represents a 36-ft diameter steel prototype. It was tested, in anchored and unanchored base configurations, under action of a time-scaled El Centro, 1940, earthquake with peak acceleration of 0.5 g, using the Earthquake Simulator Facility of the University of California, Berkeley. Stresses and displacements of the model, in both anchored and unanchored conditions, were dominated by effects of "out-of-round" response in higher-order circumferential modes, a result which is not predicted by current seismic analysis theory, and which contradicts basic assumptions of current design practice. The experimental observations are discussed in relation to dynamic analysis theory, practical design methods, and the history of tank performance in past earthquakes.

**78-1150**
**Determination of Transient Responses of a Thick-Walled Spherical Shell by the Ray Theory**
Y. Pao and A.N. Ceranoglu
Dept. of Theoretical and Appl. Mech., Cornell Univ., Ithaca, NY, J. Appl. Mech., Trans. ASME, 45 (1), pp 114-122 (Mar 1978) 11 figs, 13 refs

Key Words: Spherical shells, Transient response

The dynamic response of a thick-walled elastic spherical shell subject to radially symmetric loadings is studied by applying the theory of rays. The Fourier transformed solution of the waves in the shell is sorted out into rays by following the ray-path of the multiply reflected waves at both surfaces. Inverse transform of each ray, which is obtainable in closed form, gives rise to the exact solution of the transient response up to the arrival time of the next ray. Numerical results are shown for internally applied pressure with a step or a square-time function.

## SPRINGS

**78-1151**
**Vehicle Springs Made of Cellular Polyurethane-Elastomers - Several Years Practical Experience (Kraftfahrzeugfedern aus zelligem Polyurethan-Elastomer - Mehrjährige Erfahrungen aus der Praxis)**
G. Alicke and H. Schriever
Stormstrasse 7, 2845 Damme, Germany, Automobiltech. Z., 80 (2), pp 63-68 (Feb 1978) 12 figs, 1 table

Key Words: Springs (elastic), Suspension systems (vehicles)

Springs made of cellular Polyurethane–Elastomers have been used in the field of vehicle construction for more than 10 years. The article describes what properties are most suitable for which applications.

# SYSTEMS

## ABSORBER

(Also see Nos. 1124, 1160, 1184)

**78-1152**
**Design and Test of a Squeeze-Film Damper for a Flexible Power Transmission Shaft**
M.S. Darlow and A.J. Smalley
Mechanical Technology, Inc., Latham, NY, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication 100118, pp 43-54 (1978) 15 figs, 7 refs

Key Words: Squeeze film dampers, Power transmission systems, Shafts

For a flexible shaft designed to pass through a number of bending critical speeds, a squeeze-film damper has been designed and tested. The damper properties were selected to provide control of all critical speeds, while meeting additional constraints of high power transmission requirements and damper simplicity. The damper was fabricated and installed and its ability to control flexible shaft vibrations was demonstrated by the comparison of vibration amplitudes both with and without the damper.

**78-1153**
**Advanced Technology Helicopter Landing Gear**
R.E. Goodall

Hughes Helicopters, Culver City, CA, Rept. No. HH-77-41, USAAMRDL-TR-77-27, 151 pp (Oct 1977)
AD-A048 891/6GA

Key Words: Helicopters, Landing gear, Energy absorption, Fiber composites, Shock absorption

This report covers the work performed on the advanced helicopter landing gear program by Hughes Helicopters. The objectives of the program were to design, fabricate, and test a wheel-type advanced main landing gear concept possessing high-energy-absorbing characteristics for helicopters in the 15,000-pound class. These objectives were achieved by formulating design criteria through a data search, choosing the most cost-effective composite material, and through a design analysis, selecting the most promising landing gear concept.

**78-1154**

**Selection of Shock-Absorbers for Passive Vibration Isolation**

Z. Engel and H. Lopatowa

Nonlinear Vibration Problems. Polish Acad. Sci., Inst. of Fundamental Technol. Res., No. 18, pp 39-44 (1977) 1 fig, 6 refs

Key Words: Shock absorbers, Vibration isolation, Spring constants

This work deals with the optimal selection of spring characteristics for a mechanical single-degree of freedom system in the case of passive vibration isolation. The nonlinear spring function is linearized by employing the Kolowski method distribution function and then the optimal characteristics are selected for the linearized system.

**78-1155**

**A Practical Approach to Cab Suspension**

R. Wild

Seddon Atkinson Vehicles, Ltd., SAE Paper No. 780407, 8 pp, 9 figs

Key Words: Suspension systems (vehicles), Trucks, Ride dynamics

The purpose of the study undertaken was to determine practical methods and the respective considerations and decisions required to mount a cab to various chassis constructions. The final objective was to determine the cab structural damage incurred through the cab suspension, and to determine projected vehicle mileages on various highways before structural damage is caused.

**78-1156**

**Analytical and Subjective Ride Quality Comparison of Front and Rear Cab Isolation Systems on a COE Tractor**

W. Flower

Lord Kinematics Div., Lord Corp., SAE Paper No. 780411, 16 pp, 25 figs, 1 ref

Key Words: Ride dynamics, Tractors, Articulated vehicles, Suspension systems (vehicles)

Instrumented and subjective cab ride quality data is obtained for a COE tractor/trailer combination in which two different cab isolation systems were installed. In the first system, the rear of the cab is suspended on soft springs while the front is pinned to the frame, allowing cab pitch only. In the second system, the rear of the cab is pinned to the frame while the front is suspended on soft springs. The relative performance of these two systems is compared. Results are compared with predictions of a multi degree of freedom tractor/trailer computer model.

**78-1157**

**A Heavy Truck Cab Suspension for Improved Ride**

A.W. Foster

Ford Motor Co., SAE Paper No. 780408, 20 pp, 31 figs, 1 ref

Key Words: Suspension systems (vehicles), Trucks

This paper presents a simplified concept of the cab-over-engine tractor ride problem. It discusses ways ride can be improved and the reasons cab suspension was chosen as the preferred solution. It describes the Ford CL-9000 cab suspension, explains why it improves ride and includes some data to indicate the benefits that are realized.

**78-1158**

**A Cab Suspension for Transcontinental Operation**

A.A. Selman and T.A.H. Pixton

Ford Motor Co., Ltd., UK, SAE Paper No. 780409, 12 pp, 6 figs, 1 table

Key Words: Suspension systems (vehicles), Trucks

This paper outlines the reasons for the design of a heavy duty truck having a sophisticated cab suspension system, to cater for the special conditions of transeuropean operation. It describes the design and development of the Ford Transcontinental cab suspension, and the resulting ride performance. The unique cab tilt system used in conjunction with the cab suspension is also described.

**78-1159**
**Self-Energizing Hydropneumatic Levelling Systems**
T. Meller
Res. and Dev. Dept., BOGE G.m.b.H., Eitorf, Germany, SAE Paper No. 780052, 16 pp, 17 figs

Key Words: Suspension systems (vehicles), Vibration isolators

New hydropneumatic leveling systems with single and twin chambers are presented for application in almost all vehicle makes and types. They are self-energizing and convert the relative movement between axle and body to the advantage of height adjustment. It is shown that the units can be designed for similar body frequency within a wide range of payloads.

## ACOUSTIC ISOLATION

(See No. 1166)

## NOISE REDUCTION

(Also see Nos. 1201, 1206)

**78-1160**
**Influencing Structure-Borne Noise Characteristics of Mounting Rails of a High-Speed Diesel Engine by Vibration Absorbers (Beeinflussbarkeit des Körperschallverhaltens von Auflagerschienen eines schnellaufenden Dieselmotors durch Schwingungstilger)**
M. Saalfeld and H. Mors
Hermann-Paul St. 12a, 8000 München 50, Germany, MTZ Motortech. Z., 39 (1), pp 23-24 (Jan 1978) 6 figs, 7 refs
(In German)

Key Words: Diesel engines, Noise measurement, Noise reduction, Vibration absorption (equipment)

Sturcture-borne noise measurements on a high-performance Diesel engine (maximum rating 3308 kW at 1575 rpm) produced noise level readings showing marked overshoots in the frequency range of 400 to 1250 Hz which were independent of the prevailing engine speed.

**78-1161**
**Automobile Interior Noise Reduction Using Finite Element Methods**
D.J. Nefske and L.J. Howell
Engrg. Mech. Dept., General Motors Res. Labs., Warren, MI, SAE Paper No. 780365, 16 pp, 11 figs, 28 refs

Key Words: Noise reduction, Automobiles, Finite element technique

This paper reviews a finite element method for computing panel-excited interior noise and outlines an approach for identifying potentially noisy panels adjacent to the passenger compartment. To illustrate the potential of the analytical method, it is applied to a production automobile. A structural modification suggested by the procedure is shown to significantly reduce the low-frequency interior noise to which the occupant is exposed. Experimental verification of the method is presented.

**78-1162**
**Engine Noise Reduction Without Major Structural Design Changes (Motorgeräusch-Minderung ohne wesentliche bauliche Anderungen)**
J.M. O'Keeffe
Perkins Motoren G.m.b.H., Postfach 12, 8752 Kleinostheim, Germany, MTZ Motortech. Z., 39 (2), pp 71-73 (Feb 1978) 5 figs, 2 refs
(In German)

Key Words: Engine noise, Noise reduction

Efforts to reduce engine noise at its source by reducing energy input in the frequency range of 500-5000 Hz and by lowering the surface vibration levels using standard vibration control techniques are discussed. A reliable source ranking method is shown to be necessary for cost effective solutions and such a method, based on vibration measurement, is described. Having established the major noise sources of the engine these are then attenuated by individual treatments, which taken as a whole form a "noise package" approach which reduces the noise levels of current production engines by 6 dBA.

**78-1163**
**Experimental Approach to Reduction Technique for Engine Noise in Passenger Compartment**
T. Uchiyamada and T. Kunieda
Vehicle Evaluation and Research Dept., Toyota Motor Co., Japan, SAE Paper No. 780172, 12 pp, 14 figs, 1 table, 6 refs

Key Words: Engine noise, Noise reduction, Internal noise, Passenger vehicles

This paper deals with high frequency noise in the passenger compartment which are caused by transmitted engine noise.

For the purpose of noise reduction, several evaluation methods are developed. For the evaluation of a body transmission loss, a combination of a reverberant room and an anechoic room is used. The noise absorption of the compartment is evaluated under the concept of the saturated sound pressure level. Sufficient standard samples are measured to support the noise reduction development.

**78-1164**
**Measurement and Evaluation of the Insertion Loss of Panels**
K.S. Nordby
Systems Products Div., IBM Corp., Endicott, NY 13760, Noise Control Engr., 10 (1), pp 22-32 (Jan/Feb 1978) 30 figs, 3 tables, 13 refs

Key Words: Noise reduction, Machinery noise, Enclosures, Acoustic linings

It is shown how the insertion loss of small panels differs for random and less random sound fields typically found in small machine enclosures with and without a 25 mm thick absorptive lining. Also included are the variations created in insertion loss when absorbing liners are attached firmly or loosely to the panels.

**78-1165**
**Noise Reduction by Liquid Silencers in Hydraulic Units**
W. Herzog
British Library Lending Div., Boston Spa, UK, Rept. No. BLL-NEL-TT-2723-(6075.461), 16 pp (May 25, 1977) (Engl. transl. of Ölhydraulic und Pneumatic, West Germany, 20 (10), pp 671-675 (1976))
N78-15491

Key Words: Hydraulic equipment, Noise reduction

The effect of design parameters on noise radiation was investigated by modifying the design of a hydraulic unit. Noise propagation was obstructed by means of liquid silencers and encapsulation.

**78-1166**
**The Quiet Alloys**
L.M. Schetky and J. Perkins
International Copper Research Assn., Inc., New York, NY, Mach. Des., 50 (8), pp 202-206 (Apr 6, 1978) 3 figs, 2 tables

Key Words: Noise control, Material damping

Noise-control methods using structural and moving components from high-damping alloys are described.

**78-1167**
**Progress in the Reduction of Noise from Road Transport in the United Kingdom**
R. Taylor
Rupert Taylor & Partners, Ltd., UK, SAE Paper No. 780386, 8 pp, 1 fig, 1 table, 9 refs

Key Words: Traffic noise, Noise reduction

Noise from road transport in the United Kingdom has been a subject of three separate initiatives originated or supported by central government. Progress achieved by means of (1) compensation, sound insulation and planning controls; (2) research and development of quiet heavy goods vehicles; (3) a quiet town experiment, is discussed. The overall cost and effect of the three parallel programs is assessed along with indications for future policy.

**78-1168**
**EBF Noise Suppression and Aerodynamic Penalties**
D.J. McKinzie, Jr.
Lewis Res. Center, NASA, Cleveland, OH, Rept. No. NASA-TM-73823; E-9412, 18 pp (1978)
Sponsored by AIAA
N78-15852

Key Words: Aircraft noise, Noise reduction, Acoustic tests, Model testing

Acoustic tests were conducted at model scale to determine the noise produced in the flyover and sideline planes at reduced separation distances between the nozzle exhaust plane and the flaps of an under-the-wing externally blown flap configuration in its approach attitude. Tests were also made to determine the noise suppression effectiveness of two types of passive devices which were located on the jet impingement surfaces of the configuration. In addition, static aerodynamic performance data were obtained to evaluate the penalties produced by these suppression devices.

## ACTIVE ISOLATION

**78-1169**
**Active Ride Control – A Logical Step from Static Vehicle Attitude Control**

M.B. Packer
Automotive Products, Ltd., UK, SAE Paper No. 780050, 12 pp, 9 figs, 2 refs

Key Words: Suspension systems (vehicles), Active isolation

Soft suspension springs are an essential requirement to absorb irregularities in road surfaces without transmitting excessive acceleration forces to the vehicle. Passive attitude control systems compensate for suspension height changes due to static load variations but leave a problem of excessive body motion in response to lateral and longitudinal acceleration. In this paper a system of active ride is described which retains the advantages of a soft suspension, yet controls body pitch and roll due to braking and cornering forces. Handling quality is enhanced by precise control of front to rear roll stiffness. Computed and experimental data is presented to establish fulfillment of the design objectives.

## AIRCRAFT

(Also see Nos. 1075, 1084, 1100, 1168)

**78-1170**

**Application of the Method of Optimal Control for Elimination of Aeroelastic Vibrations**

J. Pietrucha and D. Szelag
Nonlinear Vibration Problems. Polish Acad. Sci., Inst. of Fundamental Technol. Res., No. 18, pp 45-55 (1977) 2 figs, 1 table, 23 refs

Key Words: Aircraft wings, Active flutter control, Optimum control theory

This work is concerned with the synthesis of a system which eliminates aeroelastic vibration from a wing modeled with three degrees of freedom. To this end, use is made of the Pontriagin maximum principle for a linear system with a quadratic performance index.

## BIOENGINEERING

**78-1171**

**A Modal Perspective of Lung Response**

J.J. Fredberg
Cambridge Collaborative, Inc., 238 Main St., Cambridge, MA 02142, J. Acoust. Soc. Amer., 63 (3), pp 962-966 (Mar 1978) 4 figs, 11 refs

Key Words: Bioengineering, Modal analysis, Organs (biological)

The qualitative modal structure of lung response is investigated. The average density of eigenvalues of the undamped system is estimated.

**78-1172**

**Wave Propagation in a Piezoelectric Two-Layered Cylindrical Shell with Hexagonal Symmetry: Some Implications for Long Bone**

A. Ambardar and C.D. Ferris
Dept. of Electrical Engrg., Bioengineering Program, Univ. of Wyoming, Laramie, WY 82071, J. Acoust. Soc. Amer., 63 (3), pp 781-792 (Mar 1978) 1 fig, 12 refs

Key Words: Bioengineering, Cylindrical shells, Bones, Wave propagation, Mathematical models, Piezoelectricity

Harmonic wave propagation is considered in a two-layered cylinder of dissimilar but transversely isotropic materials such as bone. The model includes the approximate piezoelectric behavior of long bone and the frequency equation is shown to constitute a 16th-order determinant. A frequency equation is derived for the nonpiezoelectric case.

## BRIDGES

**78-1173**

**Aeroelastic Flutter of Suspension Bridges**

R. Sofronie
Inst. of Civil Engrg., Bucharest, J. de Mecanique Appl., 22 (5), pp 657-674 (1977) 10 figs, 5 refs

Key Words: Suspension bridges, Flutter, Wind-induced excitation

This paper deals with a comparative analysis of the dynamic stability of suspension bridge systems subject to wind. In this analysis the wind was assumed as an incompressible horizontal fluid in steady-state flow, while the decks of suspension bridges as rigid lifting surfaces elastically clamped at the ends.

## FOUNDATIONS AND EARTH

**78-1174**

**Uniqueness of Damping and Stiffness Distributions in the Identification of Soil and Structural Systems**

F.E. Udwadia, D.K. Sharma, and P.C. Shah
Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, J. Appl. Mech., Trans. ASME, 45 (1), pp 181-187 (Mar 1978) 4 figs, 6 refs

Key Words: Interaction: soil-structure, Stiffness coefficients, Damping coefficients, Seismic design

The damping and stiffness distributions in soil-structure systems which are of importance in the linear range of response were investigated. An N-storied structure or an N-layered soil medium is modeled as a coupled, N-degree-of-freedom, lumped system consisting of masses, springs, and dampers. If mass distribution is known, the problem of identification consists of determining the stiffness and damping distributions from the knowledge of the base excitation and the resulting response at any one mass level.

## HELICOPTERS

(See No. 1153)

## HUMAN

**78-1175**

**A Pulsating Cushion that Improves Lower Body Hemodynamics of Seated Individuals**

L.D. Montgomery and E.J. Glassford
LDM Associates, San Jose, CA, SAE Paper No. 780421, 12 pp, 6 figs, 1 table, 18 refs

Key Words: Human response, Vibration tolerance, Trucks, Ride dynamics

Impedance techniques were used to measure the perfusion changes and venous clearance in the lower leg, knee, thigh and buttock that was produced by operation of a pulsating seat cushion that may reduce the detrimental hemodynamic effects of prolonged driving.

**78-1176**

**Identification of the Dynamic Characteristics of a Bench-Type Automotive Seat for the Evaluation of Ride Quality**

C.C. Smith and Y.K. Kwak
Dept. of Mech. Engrg., Univ. of Texas at Austin, TX, J. Dyn. Syst. Meas. and Control, Trans. ASME, 100 (1), pp 42-49 (Mar 1978) 12 figs, 14 refs

Key Words: Ride dynamics, Human response, Parameter identification technique, Spectrum analysis

The effect of seat transmissibility upon the spectra of motion of a typical bench-type automotive front seat is investigated. Vertical and lateral acceleration spectra are measured at the floorboard and at the man/seat interface. System transfer functions are identified from the experimental data using spectral analysis techniques.

## ISOLATION

(See Nos. 1154, 1159)

## MATERIAL HANDLING

**78-1177**

**Earthmoving Machines Require Specialized Cooling Systems**

Automotive Engineering, 86 (4), pp 32-37 (Apr 1978) 10 figs

Key Words: Earth handling equipment

Dirt, vibration, and twisting forces set cooling system requirements for earthmovers apart from those of ordinary vehicles. Means of controlling these problems are pointed out.

## MECHANICAL

**78-1178**

**Periodic Vibrations of Nonlinear Mechanical Systems**

G.N. Boiadziev
Nonlinear Vibration Problems. Polish Acad. Sci., Inst. of Fundamental Technol. Res., No. 18, pp 31-38 (1977) 9 refs

Key Words: Periodic response, Mechanical systems

The paper is concerned with the vibrations of mechanical systems modeled by certain weakly nonlinear nonautonomous differential equations. Sufficient conditions for existence of periodic solutions are given in both nonresonance and resonance case. Attention is paid on the construction of the periodic solutions.

## METAL WORKING AND FORMING

**78-1179**

**Regenerative Chatter During Cylindrical Traverse Grinding**

T. Shimizu, I. Inasaki, and S. Yonetsu

Keio Univ., Yokohama, Japan, Bull. JSME, 21 (152), pp 317-323 (Feb 1978) 17 figs, 7 refs

Key Words: Grinding (material removal), Chatter

In this paper, workpiece regenerative chatter during cylindrical traverse grinding is theoretically analyzed. The depth of cut, which is closely related to the grinding stiffness and the contact stiffness, is assumed to change stepwise in the wheel-work contact area due to the elastic deformation between the grinding wheel and the workpiece. A few experiments were carried out to discuss the theoretical results.

## RAIL

**78-1180**

**Noise Control of the Standard Light Rail Vehicle**

R.H. Spencer

Boeing Vertol Co., P.O. Box 16858, Philadelphia, PA 19142, Noise Control Engr., 10 (1), pp 4-13 (Jan/Feb 1978) 15 figs, 5 tables, 8 refs

Key Words: Railroad cars, Noise reduction

The acoustic requirements and testing involved in the development of a standard light rail vehicle for mass transportation are discussed.

**78-1181**

**Graphical Output-Oriented Computer Model of a Railroad Freight Car with Conventional Trucks**

N.W. Luttrell

Southern Pacific Transportation Co., San Francisco, CA, J. Engr. Indus., Trans. ASME, 100 (1), pp 67-78 (Feb 1978) 20 figs, 3 tables, 5 refs

Key Words: Freight cars, Railroad cars, Mathematical models

The paper describes a 13-degree-of-freedom, frequency domain, computer model of a railroad freight car riding on conventional North American three-piece trucks. These 13 degrees of freedom incorporate roll, pitch, bounce, bending, and twisting of the body, as well as lateral, swivel, and parallelogramming of each truck. This idealized freight car is driven at 200 discrete frequencies from 0.1 to 20.0 cycles per second. The driving functions are derived from the Fourier components of track geometry measurements taken from actual test tracks. Although the model is linear, coulomb damping is approximated by equivalent viscous coefficients at each frequency. Printed output is provided; however, the basic product of the program is a series of two-color graphs produced on a mechanical plotter. These include a Nyquist diagram, giving indications of the freight car's lateral stability on tangent track, and PSD plots illustrating the frequency breakdown of the various vehicle responses. Comparisons are made between the computed PSD plots and actual test data for specific conditions.

**78-1182**

**Steering Controller Design for Automated Guideway Transit Vehicles**

S.E. Shladover, D.N. Wormley, H.H. Richardson, and R. Fish

Dept. of Mech. Engrg., Massachusetts Inst. of Tech., Cambridge, MA, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (1), pp 1-8 (Mar 1978) 8 figs, 14 refs

Key Words: Automated transportation systems, Lateral response, Optimum control theory

The fundamental lateral performance capabilities of rubber-tired automated guideway transit (AGT) vehicles operating under automatic steering control on exclusive guideways are discussed. Control is achieved by steering the front wheels in response to signals derived from the position errors between the vehicle and a guideway-based reference containing random irregularities. Optimal control techniques are used to synthesize controllers which minimize a performance index consisting of mean square lateral acceleration and tracking error, defining a frontier which limits the performance of vehicles steered by a broad class of controllers.

## REACTORS

(Also see No. 1094)

**78-1183**

**Soil-Structure Interaction Analyses by Finite Elements -- State of the Art**

H.B. Seed and J. Lysmer

Dept. of Civil Engrg., Univ. of California, Berkeley, CA 94720, Nucl. Engr. Des., 46 (2), pp 349-365 (Apr 1978) 14 figs, 22 refs

Key Words: Interaction: soil-structure, Nuclear power plants, Earthquake resistant structures, Earthquake response

In this paper the authors have attempted to summarize the current capability for evaluating soil-structure interaction effects during earthquakes using finite element procedures. A concise summary of methods available, together with their capabilities and relative costs is presented.

## RECIPROCATING MACHINE

(See Nos. 1085, 1113, 1162)

## ROAD

(Also see Nos. 1068, 1069, 1073, 1081, 1082, 1087, 1095, 1096, 1098, 1099, 1116, 1118, 1155, 1156, 1157, 1158, 1160, 1161, 1163, 1175, 1176)

### 78-1184

**Simulation of Vertical Vehicle Vibrations (Die Simulation vertikalen Fahrzeugschwingungen)**

C. Voy

Fortschritt-Berichte der VDI-Zeitschriften, Series 12, No. 30, 182 pp (1977) 119 figs, taken from VDI Z., 119 (15/16), p 766 (Aug 1977) Avail: VDI Verlag G.m.b.H., Postfach 1139, 4000 Düsseldorf 1, Germany

(In German)

Key Words: Vertical vibration, Shock absorbers, Analog simulation, Digital simulation

A digital simulation method for vertical vehicle vibrations is described. Of the five models investigated only the three dimensional model, excited by four correlated time functions corresponding to street roughness, agreed with the test results. The three dimensional model was used to optimize shock absorber characteristics taking into account ride safety, comfort and the effect of surface roughness. A hybrid simulation technique is proposed in which an effective structural component of an electric analog model is integrated into an elastic-hydraulic test stand. This technique enables direct observation of how the model is affected by various changes in damping parameters and elastic stresses.

### 78-1185

**Application of the Parameter Plane Method to the Analysis of Directional Stability of Tractor-Semitrailers**

R.R. Guntur and J.Y. Wong

Dept. of Mech. and Aeronautical Engrg., Carleton Univ., Ottawa, Canada, J. Dyn. Syst., Meas. and Control, Trans. ASME, 100 (1), pp 9-17 (Mar 1978) 12 figs, 12 refs

Key Words: Tractors, Semitrailers, Articulated vehicles, Stability

This paper describes the application of the parameter plane method to the study of the effects of design and operational parameters on the directional stability of tractor-semitrailers. The location of the fifth wheel, loading conditions of the semitrailer, and cornering stiffnesses of tires are taken as parameters in the analysis. Stability boundaries for two tractor-semitrailer combinations with different brake systems are drawn on parameter planes as illustrative examples to demonstrate the utility of the method.

### 78-1186

**Summarization and Comparison of Freight Car Truck Load Data**

M.R. Johnson

Engrg. Res. Div., IIT Research Inst., Chicago, IL, J. Engr. Indus., Trans. ASME, 100 (1), pp 60-66 (Feb 1978) 18 figs, 5 refs

Key Words: Freight cars, Trucks, Data presentation, Experimental data

Methods of summarizing and presenting freight car truck load data obtained on service tests are described. Data from four separate test programs are presented in various formats. The data show considerable ranges in the load magnitudes and rates of occurrence from the various test environments. This type of information is essential for evaluating the fatigue, safety, and reliability properties of freight car truck components.

### 78-1187

**High-Speed Lateral Stability of a Freight Car Related to Modifications of Conventional Trucks**

J.A. Andresen and R. Byrne

Southern Pacific Transportation Co., San Francisco, CA, J. Engr. Indus., Trans. ASME, 100 (1), pp 49-52 (Feb 1978) 10 figs, 1 ref

Key Words: Freight cars, Trucks, Lateral stability

High speed lateral stability of freight cars is one facet of a truck performance mode requiring improvement in control. A freight car truck of conventional three-piece design was analyzed and tested on a dynamic simulator leading to recommendations for truck modifications to improve high speed lateral stability.

78-1188

**Realistic Effects of Winds on the Aerodynamic Resistance of Automobiles**

B. Dayman, Jr.

Jet Propulsion Lab., California Inst. of Tech., Pasadena, CA, SAE Paper No. 780337, 20 pp, 5 figs, 8 tables, 6 refs

Key Words: Automobiles, Aerodynamic characteristics, Wind-induced excitation, Computer programs

This paper presents the results of a rigorous computer study on the realistic effects of winds upon the aerodynamic resistance, and consequently, upon the fuel consumption of automobiles for EPA driving cycles. The aerodynamic resistance was a function of the instantaneous wind direction and speed relative to the car.

78-1189

**Dynamic Equilibrium of a Motor-Car Vehicle Under Action of Oblique Airflow**

A. Nalecz

Warszawa, Poland, Nonlinear Vibration Problems. Polish Acad. Sci., Inst. of Fundamental Technol. Res., No. 18, pp 107-145 (1977) 20 figs, 41 refs

Key Words: Motor vehicles, Aerodynamic loads

This work presents a method for constructing the equilibrium positions equations of a motor-car vehicle subject to an oblique airflow. The incoming relative air stream is deviated out from the plane of symmetry of the vehicle due to the action of an additional side wind. The three-dimensional mechanical model fo the motor-car vehicle constructed in this work is capable of representing its non-symmetric motions.

## ROTORS

78-1190

**Two Methods for the Determination of the Natural Frequencies of the System Shaft-Foundation (Zwei Verfahren zum Bestimmen der Eigenfrequenzen des Systems Welle-Fundament)**

G. Andrej

VDI Z., 120 (5), pp 213-219 (1978) 9 figs, 1 table, 14 refs

Key Words: Natural frequencies, Rotors

Two relatively simple methods are explained for the calculation of the natural frequencies of the vibration system "rotating shaft - foundation." On the basis of the graphical solutions derived by means of these new methods, the influence of alternations of individual parameters can be looked over in a simple manner.

78-1191

**The Influence of Manufacturing Tolerances on Multi-Lobe Bearing Performance in Turbomachinery**

R.G. Kirk

Turbo Products Div., Ingersoll-Rand Co., Phillipsburg, NJ, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication 100118, pp 108-129 (1978) 15 figs, 4 tables, 7 refs

Key Words: Turbomachinery, Rotor-bearing systems, Fluid-film bearings

The manufacturer of turbomachinery is confronted with the problems of design tolerances on all machined parts comprising a given compressor or turbine. The tolerances on the majority of the machined parts have a direct or indirect influence on the resulting dynamic response of the rotor bearing system. One of the most critical tolerances that must be held is the one on the profile of the multi-lobe bearing. The fluid-film bearing is one focus point for theoretical optimization of rotor-bearing system response sensitivity and stability. The analytical model of the fluid film bearing is based upon a precise definition of the bearing profile. This paper reviews the current standard analytical modelling assumptions for multi-lobe bearing designs and compares these assumptions to design tolerances and to actual machined bearing profiles.

78-1192

**The Estimation of Parameters in a Linear Rotor-Bearing System Model**

E. Woomer and W.D. Pilkey

Dept. of Mech. and Aerospace Engrg., School of Engrg. and Appl. Science, Univ. of Virginia, Charlottesville, VA, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication 100118, pp 157-169 (1978) 3 figs, 4 tables, 9 refs

Key Words: Rotor-bearing systems, Parameter identification technique

The problem of identifying unknown parameters in a linear

rotor-bearing system model is discussed. The measurements of displacements caused by a trial mass unbalance applied to the rotor are used along with the linear algebraic equations which describe the rotor steady-state sinusoidal motion to provide a means of selecting values of model parameters such that the fit between the measured and computed rotor responses is optimized. Several approaches to the optimization are discussed, and three example problems are included.

**78-1193**

**Fast Fourier Transform Analysis of Rotor-Bearing Systems**

K.C. Choy, E.J. Gunter, and P.E. Allaire

Dept. of Mech. and Aerospace Engrg., School of Engrg. and Appl. Science, Univ. of Virginia, Charlottesville, VA, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication 100118, pp 245-272 (1978) 13 figs, 24 refs

Key Words: Rotor-bearing systems, Fluid-film bearings, Modal analysis, Fast Fourier transform

Nonlinear transient analysis of rotor-bearing systems is becoming increasingly important in the analysis of modern-day rotating machinery to model such phenomena as oil film whirl. This paper develops an analysis technique incorporating modal analysis and fast Fourier transform techniques to analyze rotors with residual shaft bow and realistic nonlinear bearings. The technique is demonstrated on single-mass and three-mass rotor examples. Comparisons of the theoretical results with experimental data give excellent agreement.

**78-1194**

**The Transient Response of a Balanced Rigid Rotor Running in Squeeeze Film Supported Journal Bearings**

L.J. McLean and E.J. Hahn

School of Mech. and Industrial Engrg., The Univ. of New South Wales, Kensington, N.S.W., Australia, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication 100118, pp 203-229 (1978) 13 figs, 29 refs

Key Words: Rotor-bearing systems, Fluid-film bearings, Transient response, Hybrid simulation

The equations governing the transient behavior or rotors supported in dual film hydrodynamic bearings can be time consuming and difficult to solve using digital computers. A convenient method for solving these equations using hybrid computers is outlined and its utility illustrated by investigating the transient behavior of a balanced unidirectionally loaded rigid rotor running in unpressurized ($\pi$ film) simple journal bearings supported by centrally preloaded, fully pressurized ($2\pi$ film) squeeze film bearings. The short bearing approximation is used to evaluate the fluid film forces although finite bearing solutions could also be implemented without affecting the generality of the approach.

**78-1195**

**Effects of Shaft Warp and Disk Skew on the Synchronous Unbalance Response of a Multimass Rotor in Fluid Film Bearings**

D.J. Salamone and E.J. Gunter

Compressor Div., Allis-Chalmers Corp., Milwaukee, WI, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication 100118, pp 79-107 (1978) 11 figs, 4 tables, 11 refs

Key Words: Shafts, Rotor-bearing systems, Fluid-film bearings, Unbalanced mass response

The paper deals with the analysis of the synchronous unbalance response of a multi-mass flexible rotor in linearized fluid film bearings including shaft bow and disc skew. To illustrate the importance of including disk skew and shaft warp in the dynamical equations, several synchronous response cases are presented, including the evaluation of a large industrial motor driven water pump.

**78-1196**

**The Influence of Tilting Pad Bearing Characteristics on the Stability of High Speed Rotor-Bearing Systems**

J.C. Nicholas, E.J. Gunter, and L.E. Barrett

Dept. of Mech. and Aerospace Engrg., School of Engrg. and Appl. Science, Univ. of Virginia, Charlottesville, VA, "Topics in Fluid Film Bearing and Rotor Bearing System Design and Optimization," S.M. Rohde, P.E. Allaire, and C.J. Maday, Eds., ASME publication 100118, pp 55-78 (1978) 12 figs, 6 tables, 20 refs

Key Words: Dynamic stability, Rotor-bearing systems, Tilting pad bearings

A computer design optimization for tilt pad bearings is developed. A stability analysis is carried out for an 11-stage centrifugal compressor supported by 8 geometrically different pairs of 5-pad tilt pad bearings. The compressor

represents a typical class of machine with a relatively flexible shaft often encountered in industry.

## SELF-EXCITED

**78-1197**

**A Flutter Analysis of a System of Two Airfoils with Aerodynamic Interference**

J. Grzedzinski

Arc. Mech. Strosowanej, 30 (1), pp 47-64 (1978)

Key Words: Flutter, Airfoils, Aerodynamic characteristics

A theoretical study is made of the influence of an aerodynamic interaction of two thin profiles in the plane flow of an ideal gas on the critical flutter velocity. Presented are results of calculations of aerodynamic coefficients and the flutter velocity for biplane profiles and profiles laying on the straight line one behind the other.

## SHIP

**78-1198**

**Structural Dynamic Problems in Ships and Other Marine Structures**

H.A. Kamel and D. Liu

Dept. of Mech. and Aerospace Engrg., Univ. of Arizona, Tucson, AZ, "Finite Element Applications in Vibration Problems," M.M. Kamal and J.A. Wolf, Jr., Eds., ASME publication H00102, pp 41-66 (1978) 8 figs, 168 refs

Key Words: Ships, Off-shore structures, Dynamic structural analysis

The paper presents a comprehensive survey of the problems involving dynamics in ships and other marine structures. Emphasis is given to the source and nature of the various dynamic loadings encountered by marine structures in the ocean environment, and their resulting dynamic behavior. Analytical techniques, such as strip theory and the finite element method, used to predict the loads and structural responses of these structures for design and analysis purposes are briefly discussed. The status of experimental work aimed at clarifying the fundamental nature of the loads and responses is reviewed.

**78-1199**

**Some Extensions of the Classical Approach to Strip Theory of Ship Motions, Including the Calculation of Mean Added Forces and Moments**

T.A. Loukakis and P.D. Sclavounos

Dept. of Naval Architecture and Marine Engrg., National Tech. Univ. of Athens, Athens, Greece, J. Ship Res., 22 (1), pp 1-19 (Mar 1978) 21 figs, 27 refs

Key Words: Ships, Equations of motion, Forced vibration

The application of the dynamical theory to the problem of a ship moving with constant forward speed on a free surface has been extended to include the exciting forces in oblique regular waves. As a result, it has become possible to derive a new formulation for the equations of motion, for a ship moving with five degrees of freedom. The application of the same theory has yielded formulas for the calculation of the mean added resistance and drift force in oblique regular waves and the calculation of all mean forces and moments for the forced oscillations of a ship in calm water.

## SPACECRAFT

(Also see No. 1101)

**78-1200**

**Dynamic Response Analysis of Spacecraft Structures Based on Model Survey Test Data Including Nonlinear Damping**

M. Degener

Inst. f. Aeroelastik, Deutsche Forschungs- und Versuchsanstalt f. Luft- und Raumfahrt, Göttingen, West Germany, Rept. No. DLR-FB-77-17, 59 pp (1977)

(In German)

N78-14092

Key Words: Spacecraft, Dynamic response, Launching response

Theoretical and experimental methods to determine the dynamic response of a spacecraft to the loads acting at the structure during launch and mission were compared. As one of the possible methods the general procedure of dynamic response calculations on the basis of experimental data, measured in a modal survey test, is presented. Special emphasis is given to the importance of the nonlinear damping behavior, which must be taken into account; for the dynamic response analysis.

**78-1201**

**Acoustic Noise Control in a Manned Space Vehicle – The Overall Approach for Spacelab**

D. Wyn-Roberts
European Space Res. and Tech. Center, Noordwijk, Netherlands, Rept. No. ESA-TN-137, 19 pp (Sept 1977)
N78-15857

Key Words: Spacecraft, Noise control

An important aspect of manned spaceflight is the control of the ambient-noise level inside the vehicle during orbital operations. This is particularly critical for Spacelab, since scientist astronauts will be required to operate sophisticated experiments inside the module. The overall approach used to obtain a controlled, low ambient-noise level in the Spacelab module is described. The various noise sources are identified, and an analysis and prediction of the overall noise level are made. Recommendations are then made regarding the noise-control methods required, together with a test program for verifying the effectiveness of these methods.

**78-1202**
**Some Design Considerations for Large Space Structures**
H.G. Bush, M.M. Mikulas, Jr. and W.L. Heard, Jr.
Langley Res. Center, NASA, Hampton, VA., AIAA J., 16 (4), pp 352-359 (Apr 1978) 15 figs, 2 tables, 8 refs

Key Words: Spacecraft, Space shuttles, Trusses, Design techniques

Physical characteristics of large skeletal frameworks for space applications are investigated by analyzing one concept: the tetrahedral truss, which is idealized as a sandwich plate with isotropic faces. Appropriate analytical relations are presented in terms of the truss column element properties, which, for calculations, were taken as slender graphite/epoxy tubes.

## STRUCTURAL

**78-1203**
**Cable Car Loading Phenomena (Über Belastungsvorgange bei Seilbahnen)**
Fortschritt-Berichte der VDI Zeitschr (Progress Reports of the Association of German Engineers), Series 13, No. 17, 100 pp (1977) Taken from VDI Z., 119 (15/16), p 800 (Aug 1977) Avail: VDI-Verlag G.m.b.H., Postfach 1139, 4000 Düsseldorf 1, Germany
(In German)

Key Words: Cable cars, Impact load prediction

A cable car experiences a multitude of loading phenomena, such as passenger boarding, braking, going over supports, and longitudinal wave loads in steel wire cables. The derivation of an impact factor for the determination of maximum deflection, which takes into consideration loading that is characteristic to cable cars, is described.

## TRANSMISSIONS
(Also see Nos. 1110, 1111)

**78-1204**
**The Effect of Various Limiting Quantities on the Torsional Vibration Behavior of a System with Universal Joint Drives and the Possibilities for the Reduction of Torsional Vibrations (Auswirkungen verschiedener Einflussgrössen auf das Drehschwingungsverhalten eines Systems mit eingebauten Kreuzgelenkgetrieben und Möglichkeiten zur Reduzierung der Drehschwingungen)**
W. Hein and W. Stühler
Fortschriftt-Berichte der VDI-Zeitschriften, Series 11, No. 27, 80 pp (1977) 50 figs, Taken from VDI Z., 119 (15/16), p 774 (Aug 1977) Avail: VDI-Verlag G.m.b.H., Postfach 1139, 4000 Düsseldorf 1, Germany
(In German)

Key Words: Torsional vibration, Universal joints, Power transmission systems, Vibration control

Dynamic behavior of systems with universal joint drives are reviewed. The differences in solution of forced and of parametrically excited vibrations in linear and nonlinear cases are investigated. The effects of limiting quantities on the stability and resonance are discussed, and the possibilities for the reduction of torsional vibrations of elastic systems are indicated. This report presents the results of an earlier dissertation by W. Hein, providing the designer with a tool for controlling possible vibration problems in rotating drive lines with universal joint drives.

**78-1205**
**Investigation of Dynamic Phenomena in Drive Systems with Clearance Fits (Untersuchung Dynamischer Erscheinungen in Spielbehafteten Antriebssystemen)**
M. Boshenko
Tech. Univ., Dresden, Germany, Maschinenbautechnik, 26 (10), pp 457-461 (1977) 12 figs, 3 tables,

24 refs
(In German)

**Key Words:** Transmission systems, Dynamic properties

The influence of the clearance and the importance of the characteristic line slope of a slip-ring induction motor are investigated by means of the minimum model of a drive. A more exact computation of drives with clearance fits at any starting characteristic and larger models is possible only by means of electronic computers.

**78-1206**
**Noise Reduction in Hydraulic Drive Systems for Machine Tools**
K. Schoeller
British Library Lending Div., Boston Spa, UK, Rept. No. BLL-NEL-TT-2715-(6075.461), 14 pp (1977) (Engl. transl. from Oelhydraulic und Pneumatic, 20 (6), pp 387-390 (1976))
N78-14403

**Key Words:** Fluid drives, Noise reduction

Noise reduction in installations as comprehensive as transfer lines was discussed as being achieved by an entire package of measures headed by the choice of a low noise pump. Various reduction measures such as carcass noise insulation, pulsation dampers, hydraulic units, and improvement of pumps were suggested and discussed in detail.

**78-1207**
**Higher Load and Speed Limits for Silent Chain**
A.M. McCarty and R. Stevenson
Industrial Chain Div., Morse Chain Div., Borg-Warner Corp., Ithaca, NY, Mach. Des., 50 (1), pp 121-125 (Jan 12, 1978)

**Key Words:** Chains, Power transmission systems, Noise reduction, Vibration control, Design techniques

Improved link and joint designs allow silent chain to operate at higher speeds and loads than ever before. These higher capacities, combined with inherent compactness and low vibration, make silent chain an efficient alternative to belt, gear, and roller-chain drives.

## USEFUL APPLICATION

**78-1208**
**Resonant-Mass System Senses Liquid Density**
R.F. Stengel
Pasadena, CA, Design News, 34 (4), pp 72-73 (Feb 20, 1978) 5 figs

**Key Words:** Measuring instruments

A resonant-mass system for measuring liquid density in process industries as it flows through the equipment is described. It consists of a straight smooth bore tube forming part of a resonant mass system that includes two symmetrically placed cantilever masses.

# AUTHOR INDEX

# TECHNICAL NOTES

J.E. Brock
**Lower Bounds for Gravest Torsional Frequencies**
J. Appl. Mech., Trans. ASME, 45 (1), pp 197-198 (Mar 1978) 5 refs

F. Weidenhammer
**A Relativistic Harmonic Oscillator and Its Time Element (Der Relativistische Harmonische Oszillator in Seiner Eigenzeit)**
Z. angew. Math. Mech., 57 (12), pp 721-722 (Dec 1977) 3 refs

T. Sato, K. Sasaki, O. Ikeda, S. Wadaka, T. Sunada, M. Nonaka, J. Ishii, Y. Nakamura, and K. Endo
**Acoustical Imaging Systems Using Random Signal Analyses**
J. Sound Vib., 55 (4), pp 596-599 (Dec 22, 1977) 3 figs, 12 refs

N.C. Mahanti
**Oscillation Modes in Superposed Fluids**
J. Appl. Mech., Trans. ASME, 45 (1), pp 204-205 (Mar 1978) 1 table, 4 refs

P.R. Conigliari
**Resonance in Stubby Cantilevers**
Mach. Des., 50 (8), pp 254-255 (Apr 6, 1978)

W. Roth
**Torsional Vibration of a Stretched Band (Torsionsschwingungen des Gezogenes Bandes)**
Z. angew. Math. Mech., 57 (12), pp 722-725 (Dec 1977)

H.B. Khurasia and S. Rawtani
**Vibration Analysis of Circular Plates with Eccentric Hole**
J. Appl. Mech., Trans. ASME, 45 (1), pp 215-217 (Mar 1978) 3 figs, 5 refs

D.L. Taylor
**Wheel Rotations and Trailer Dynamics**
J. Appl. Mech., Trans. ASME, 45 (1), pp 206-207 (Mar 1978) 1 fig, 4 refs

F.R. Archibald
**Torsional Stiffness of Rubber Shock Mounts**
Mach. Des., 50 (8), p 253 (Apr 6, 1978)

# CALENDAR

## SEPTEMBER 1978

11-13 **IUTAM Symposium on Variational Methods in the Mechanics of Solids,** [U.S. Army Research Office & National Science Foundation & Northwestern University] Evanston, IL *(Prof. S. Nemat-Nasser, Dept. of Civil Engrg., Northwestern Univ., Evanston, IL 60201 - Tel. (312) 492-5513)*

11-14 **Off-Highway Meeting and Exposition,** [SAE] MECCA, Milwaukee, WI *(SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096 - Tel. (412) 776-4841)*

24-27 **Design Engineering Technical Conference,** [ASME] Minneapolis, MN *(ASME Hq.)*

## OCTOBER 1978

3-5 **Army Symposium on Solid Mechanics** [AMMRC] Cape Cod, MA *(AMMRC. Attn: DRXMRT, Watertown, MA 02172 - Tel. (617) 923-3253)*

8-11 **Diesel and Gas Engine Power Conference and Exhibit,** [ASME] Houston, TX *(ASME Hq.)*

8-11 **Petroleum Mechanical Engineering Conference,** [ASME] Houston, TX *(ASME Hq.)*

17-19 **49th Shock and Vibration Symposium,** [U.S. Naval Research Lab.] Washington, D.C. *(H.C. Pusey, Director, The Shock and Vibration Info. Ctr., Code 8404, Naval Res. Lab., Washington, D.C. 20375 - Tel. (202) 767-3306)*

17-19 **Joint Lubrication Conference,** [ASME] Minneapolis, MN *(ASME Hq.)*

24-26 **Stapp Car Crash Conference** [SAE] University of Michigan, Ann Arbor, MI *(SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096 - Tel. (412) 776-4841)*

## NOVEMBER 1978

26-30 **Acoustical Society of America** [ASA] Salt Lake City, UT *(ASA Hq.)*

26-Dec 1 **Acoustical Society of America, Fall Meeting,** [ASA] Honolulu, Hawaii *(ASA Hq.)*

27-30 **Aerospace Meeting,** [SAE] Town & Country, San Diego, CA *(SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096 - Tel. (412) 776-4841)*

## DECEMBER 1978

4-6 **15th Annual Meeting of the Society of Engineering Science, Inc.,** [SES] Gainesville, FL *(Prof. R.L. Sierakowski, Div. of Continuing Education, Univ. of Florida, 2012 W. University Ave., Gainesville, FL 32603)*

10-15 **Winter Annual Meeting,** [ASME] San Francisco, CA *(ASME Hq.)*

11-14 **Truck Meeting,** [SAE] Hyatt Regency, Dearborn, MI *(SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096 - Tel. (412) 776-4841)*

## FEBRUARY 1979

26-Mar 2 **Congress & Exposition,** [SAE] Cobo Hall, Detroit, MI *(SAE Meetings Dept., 400 Commonwealth Dr., Warrendale, PA 15096 - Tel. (412) 776-4841)*

## JUNE 1979

11-15 **Acoustical Society of America, Spring Meeting,** [ASA] Cambridge, MA *(ASA Hq.)*



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## CALENDAR: ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass. Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St., N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

ARS: American [illegible] Society
[illegible]
New York, NY [illegible]

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 47th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 47th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
[illegible]

[illegible]

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
[illegible]
[illegible], UK

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers
[illegible]
New York, NY [illegible]

[illegible]